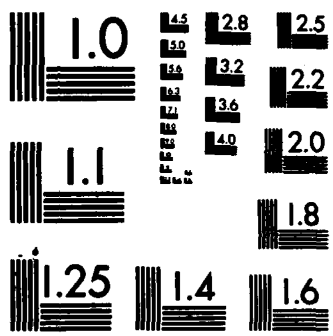
AD-A141 051 A SYSTEM DYNAMICS APPROACH TO MEASURING THE VALUE OF INFORMATION(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF ENGINEERING M M KABIL DEC 83 1/2

UNCLASSIFIED AFIT/GOR/OS/83D-6 F/G 5/1 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AFIT/GOR/OS/83D-6

AD-A141 051

A SYSTEM DYNAMICS APPROACH TO

MEASURING THE VALUE OF INFORMATION

THESIS

Mohamed Magdy Kabil
Colonel, Egypt

AFIT/GOR/OS/83D-6

DTIC FILE COPY

DTIC
ELECTE
MAY 15 1984
S D
E

Approved for public release; distribution unlimited

84 05 15 055

AFIT/GOR/OS/83D-6

A SYSTEM DYNAMICS APPROACH TO MEASURING THE VALUE OF INFORMATION

THESIS

Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Operations Research

and Systems Analysis

Accession For	
NTIS GRA&I	☒
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

Mohamed Magdy Kabil, B.S., M.Sc.
Colonel, Egypt

December 1983

Approved for public release; distribution unlimited

AFIT/GOR/OS/83D-6

A SYSTEM DYNAMICS APPROACH TO

MEASURING THE VALUE OF INFORMATION

Mohamed Magdy Kabil, B.S., M.Sc.
Colonel, Egypt

Approved:

____ _______

____ _______

Accepted:

____

Dean, School of Engineering

Acknowledgements

I would like to thank my thesis advisor, Lieutenant Colonel Tomas Clark, Jr. , USAF, Professor of Systems Management for his most valuable advice and guidance throughout the study. I would also like to thank Dr. Robert F. Allen, Professor of Economics for his helpful remarks. Finally, I am indebted to my family members for their tolerance, encouragement, and love.

Mohamed Magdy Kabil

December 1983.

Table of Contents

List of Figures

List of Tables

AFIT/GOR/OS/83D-6

Abstract

Developing a computerized national information system in Egypt is under investigation. The justification for introduction of such a system is discussed through a System Dynamics approach. The value of information is assessed by studying the effects of changes in information quality attributes on the national development process.

The study provides a System Dynamics model of the national development process. Building upon the governmental policy for development, the model is divided into five main sectors; demographic, military, labor, capital, and housing sector. The five sectors are integrated and tested as a single unit.

In the model construction, decisions are modeled as a combination of information flows describing the status and objectives of the system. Information entering a decision is assumed to be available with certain levels of accuracy and timeliness. Those levels are changed through two experiments which measure different effects on the objectives of national development. Finally, recommendations are introduced for further research which will enhance the model's usefulness for both information evaluation and other policies of development.

THIS DOC

Reproduced from best available copy.

SYSTEM DYNAMICS AS A TOOL FOR INFORMATION SYSTEM DESIGN

I. INTRODUCTION

Definition of the Problem

Throughout the long history of Egypt, the government has had a significant role in forming the future of the country. The eras of development and the eras of stagnation refer to the high or low quality of governmental decisions. The people have always looked to the quality of the governmental decisions as an indication of the quality of life in the future. The quality of governmental decisions and control depends on the quality of information they are built upon. This fact led to a proposition of developing a computerized national information system [17:165].

The justification for the introduction of a new information system usually lies on comparative "cost-saving" grounds; how much it costs to obtain the information with the new system by comparison with the old [40:39]. This is certainly an important criterion and one which usually can be expressed and realized in concrete figures. In the case of developing a new national information system, however, the criterion fails to attach adequate importance on the impact the new information may have on performance of the

total system. More accurate information, or more timely information, does not guarantee better performance for the system as a whole. The value of information can only be assessed from the changes in organizational stability which accompany its use [41:57]. In other words, information may have a value to the government which is independent of the cost of obtaining it. This value is related to the effects the information has on the development of the country, something which is often very difficult to estimate in advance and for this reason, often goes unestimated. As Forrester states [5:427] :

> "Better information is worth the value we attach to the improved industrial performance which results when better information is available. Unless we can determine the change in system performance that will result from a changed information flow we cannot determine its value. The value of information has usually been determined by highly subjective means that necessarily include an estimate of what the information will do to the dynamic behavior of the system. Our ability to estimate the characteristics of information-feedback systems is poor. It is to be expected that one of the weakest areas of managerial judgment is in placing a dollar value on an information source."

This research is concerned with the link between the structure of information and national development. The concern is formulated specifically in the next two sections.

Problem Statement

Developing a computerized national information system in Egypt is under investigation. There is no completed dynamic

model that is capable of capturing the effects of changes in the structure of information on national development. Such a model will enable the decision maker to assess the value of information and estimate the benefits of developing such a system. The model would also provide a vehicle for system analysts to use in understanding the requirements and characteristics of the information system.

Research Objectives

The primary objective of the research is to develop a dynamic model which captures the relationships between the structure of information and the national development process. The model is used to investigate the impact of information structure changes on government policies for national development. It is also used to assess the value of information and estimate the benefits of the proposed information system. In addition, the model may be used to discuss the requirements and characteristics of the information system. These objectives are approached within a specific scope which is defined in the next section.

Scope

The research is directed at understanding and modeling the effects of the quality of information on the national development process. It considers the two attributes of information; timeliness and accuracy. These attributes are

the ones most commonly associated with information quality [14,23,26,37,39]. The policies considered in the national development process are compiled from the official publications about the current five-year plan for national development. The model is developed at a high level of aggregation and primarily is intended to portray trends of the major variables which already exist rather than contingent variables which may be considered in further research. Within these limitations, the research is performed using the methodology explained in the next section.

Methodology

The methodology applied in this research is that of System Dynamics. It is defined as:

> "the study of the information-feedback characteristics of industrial activity to show how organizational structure, amplification (in policies), and time delays (in decision and actions) interact to influence the success of the enterprise. It treats the interactions between the flows of information, money, orders, materials, personnel, and capital equipment in a company, an industry, or a national economy." [5,13].

There are four main factors in this selection. The first is the applicability of System Dynamics to large dynamic systems such as national development systems [18:557,28:20]. The second is its capability to simulate the time varying behavior of the interaction between system components and information feedback loops [5:14]. The third

is its use of formal, quantitative computer models which may be considered as experimental tools [5:17]. They allow repeated experimentation with the system, testing assumptions, or altering government policies. The fourth is its usefulness for policy analysis and problem solving on consecutive phases at the national level [7].

System Dynamics, or Industrial Dynamics as it was first introduced, was developed at the Massachusetts Institute of Technology (M.I.T.) School of Industrial Management by Jay W. Forester in the late 1950s. Applications of the System Dynamics approach include a world resources model [9,22], industrial research and development [33], weapon systems acquisition [43], business planning [3], industry modeling [15], and resource management [8].

The problems that have been addressed from the perspective of System Dynamics have at least two features in common. First, they are dynamic, in the sense that they involve quantities which change over time. The second feature involves the notion of feedback which has appeared to engineers in servo-mechanisms and closed-loop control systems, to physiologists as homeostasis, and to social scientists as the notion of the vicious circle and the self-fulfilling prophecy. These two features of time varying behavior and information feedback are clearly typical of the problem of this research.

Forrester[4,5,6] and Richardson and Pugh [32] explain

the System Dynamics approach to policy analysis and problem solving. The approach tends to look within a system for the sources of its problem behavior. It isolates those portions of a system, its environment, and information flows within a system that relate to a perceived problem or required policy. This internal point of view results in models of feedback systems that bring external agents inside the system. Once the model is developed, it can be modified to reflect changes to the system or environment and used to analyze new problems or proposed changes to the system. Table 1.1 contains the stages of the System Dynamics approach as given by Forrester [5:13] and Richardson and Pugh [32:16]. However, Richardson and Pugh emphasize the idea that final policy recommendations from a System Dynamics study come not merely from manipulations with the formal model but also from the additional understandings one gains about the real system by iterating at a number of stages in the modeling process (figure 1.1).

In this research the methodology is applied through three main phases. First, the modeling of information structure ch[illegible] is discussed. Next, a System Dynamics model of th[illegible]al development process is developed. Finally, a ser[illegible] experimentations is performed to assess the value of more timely and more accurate information. The applied methodology forms the order of presentation of the research as described in the following section.

FORRESTER	RICHARDSON-PUGH
1. Identify a problem.	1. Problem identification and definitions.
2. Isolate the factors that interact to create the observed symptoms.	
3. Trace the cause-and-effect information-feedback loops that link decisions to action to resulting information changes and to new decisions.	2. System conceptualization
4. Formulate decision policies that describe how decisions results from available information streams.	3. Model formulation
5. Construct a mathematical model of the decision policies, information sources, and interaction of the system components.	
6. Generate system behavior through time with the model.	4. Analysis of model behavior.
7. Compare results to historical data from the actual system.	
8. Revise the model until it is an acceptable representation of the actual system.	5. Model evaluation.
9. Use the model to test modifications to the system.	6. Policy analysis.
10. Alter the real system in directions the model has shown will lead to improved performance.	7. Model use or implementation.

Table 1.1. The Stages of the System Dynamics Approach

[5:13,32:16]

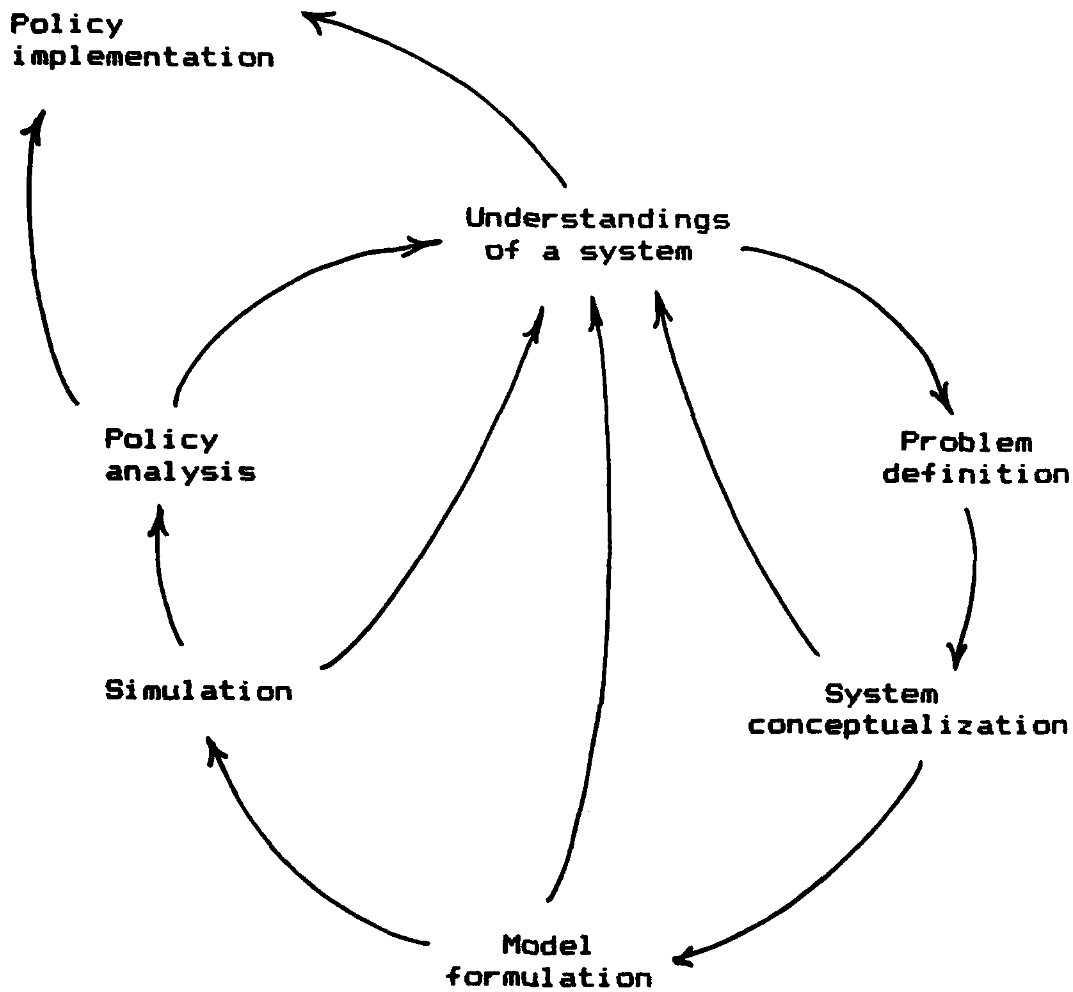


Figure 1.1. The Iterative Nature of the System Dynamics Approach [32:Fig.1.1]

Order of Presentation

Five chapters are presented to report this research (figure 1.2). Discussed in chapter two, are the definitions and modeling of information and changes in information quality attributes. Included in chapter three are discussions of the conceptualization, formulation, and operation of the model of the national development process. The testing and validation of the model are dealt with in chapter four. Presented in chapter five are the experimentations, findings, and recommendations for continuing study.

Summary

Conceiving the importance of the government role, a national information system has been proposed. The problem, which is related to the justification of such a system, has been defined in detail. The research objectives and scope have been established and the research methodology and the order of presentation have been described. Discussed in next chapter, are the definitions, basic concepts, and modeling of changes in information quality attributes.

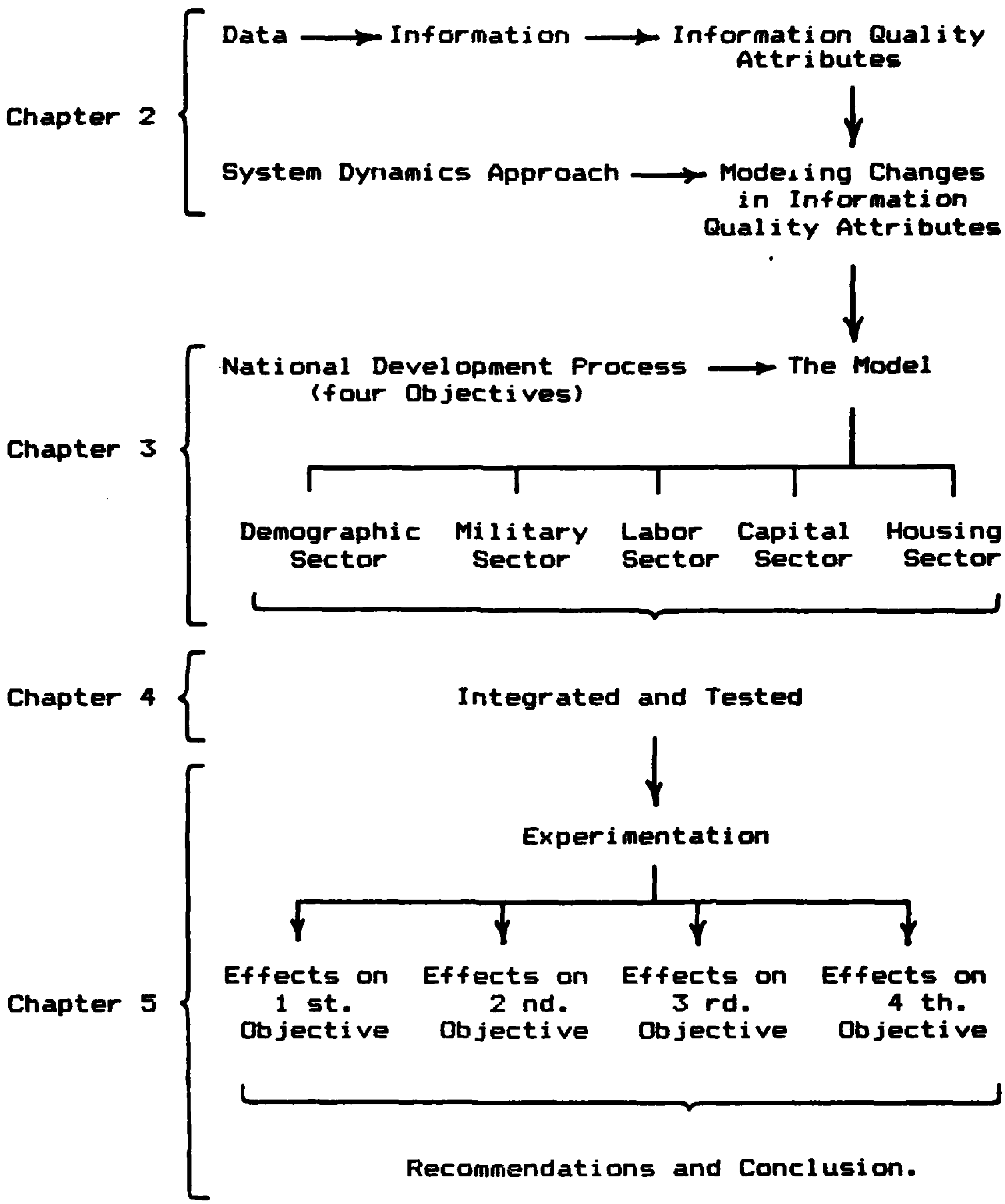


Figure 1.2 Order of Presentation.

II. Definitions and Basic Concepts

Introduction

In chapter one, the research methodology is presented in general. This chapter introduces the definitions and basic concepts which were used throughout the course of the study. First, definitions and basic concepts of information quality attributes are presented. Next, main tools of System Dynamics are reviewed. Those tools are causal-loop diagram, flow diagram, and DYNAMO equations. Finally, the representation of information flow in System Dynamics models is discussed, and methods of simulating changes in information quality attributes are addressed.

Information Quality Attributes

The popular interpretation of the term information has semantic and pragmatic implications, that is, information has meaning and is practically useful for something. Most authors stress that these implications constitute the fundamental difference between data and information [36:142, 42:2]. Data are transformations of observable environmental phenomena. Information is that subset of data which, after having been evaluated with respect to some purposeful activity has been judged "useful". The usefulness (or fitness for use) is the definition of the term "quality" as stated by Juran [19:1-2].

Viewing information as useful data gives rise to several fundamental properties of information. The usefulness or value of something is dependent upon the overall context in which it is to be used and the time at which it is available with respect to when it is needed. So, information is a situation-dependent and time-dependent phenomenon. Also, since situation dependence includes a consideration of whom the information is to be used by and what it is to be used for, information is specifically user-dependent and use-dependent.

Time dependence of information leads to two of its quality attributes which are timeliness and response time. Timeliness is defined as "the degree to which information is up to date" [21:283], or "the age of the information when it is available for decision making" [14:10]. Response time is defined as "the speed of retrieving sought information" [21:283], or "the length of time between the manager's (user's) querying data base and getting an answer." [20:84].

User dependence of information leads to another two attributes which are completeness and relevance. Completeness is defined as "the thoroughness of information in relation to that sought (by the user)" [18:283]. Relevance is defined as "the ability to provide that information, and only that information, which is desired (by the user)" [21:283].

Use-dependence of information also leads to two of its

quality attributes which are accuracy and reliability. Accuracy is defined as "the correctness of information in reflecting reality" [21:283]. Reliability is defined as "the certainty that sought information is available" [21:283].

On the level of aggregation the research deals with, the most important attributes of information quality are timeliness and accuracy. The timeliness attribute represents the time-dependence of information; and the accuracy attribute represents the situation dependence of information. Before discussing how System Dynamics models the changes in those attributes, the following three sections introduce the three main tools of System Dynamics; causal-loop diagram, flow diagram, and DYNAMO statements.

Causal-Loop Diagram

Causal thinking and information feedback are the keys of organizing and communicating ideas in this study and in most System Dynamics studies. Typically an analyst isolates key causal factors and diagrams the system of causal relationships before proceeding to build a computer simulation model. But causal chains can often be linked together nearly endlessly to create an undisciplined morass of causal relationships. So, causal-loop diagrams only focus on causal relationships which comprise circular chains or causal loops. Within a causal loop an initial cause

ripples through the entire chain of causes and effects until the initial cause eventually becomes an indirect effect of itself (feedback) [1]. Two important things occur when limiting attention to closed-loop feedback. First, the number of factors or variables to be included within a system's definition can be reduced to a manageable level. Second, attention can be focused on those variables that are most important in generating and controlling system's problems.

In social and economic systems causal statements usually include an "other things being equal" provision. To correctly diagnose a causal influence, one must perform the mental experiment of asking what would happen if the particular causal influence under consideration were the only influence to act upon the affected object [34:12].

Figure 2.1 is an example of causal-loop diagram which depicts interactions of population, births, and deaths. As shown in the figure, the individual links in such diagrams can be labeled to show whether the nature of the causal-link is "positive" or "negative". A plus sign indicates that the variables at the opposite ends of the arrow tends to move in the same direction (direct variation) while a minus sign indicates an inverse relationship.

Reading around a feedback loop the cumulative effects of its causal links gives an idea of the character of the loop. A feedback loop is positive if it contains an even number of

negative causal links. A feedback loop is negative if it contains an odd number of negative causal links. So, the polarity (sign) of a feedback loop is the algebraic product of the signs of its links. Positive feedback loops amplify deviations and distabilize, while negative feedback loops strive to control and stabilize.

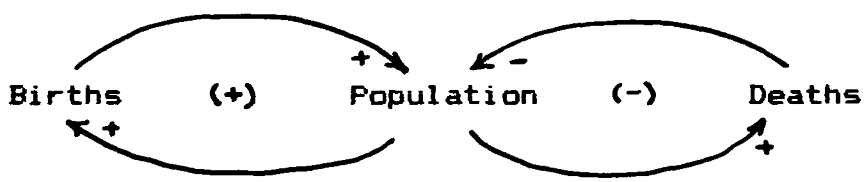


Figure 2.1 Causal-Loop Diagram of Interactions of Population, Births, and Deaths

Flow Diagram

The first step in moving from a causal-loop representation to a computer simulation model is the identification of system levels and rates. A level is a quantity that accumulates over time, and a rate is an activity, or movement, or flow that contributes to the change per unit of time in a level. In identifying a system's levels and rates it is helpful to represent the system in flow diagram form [1]. Figure 2.2 depicts the symbols that are used to represent levels, rates, and auxiliaries in flow diagrams.

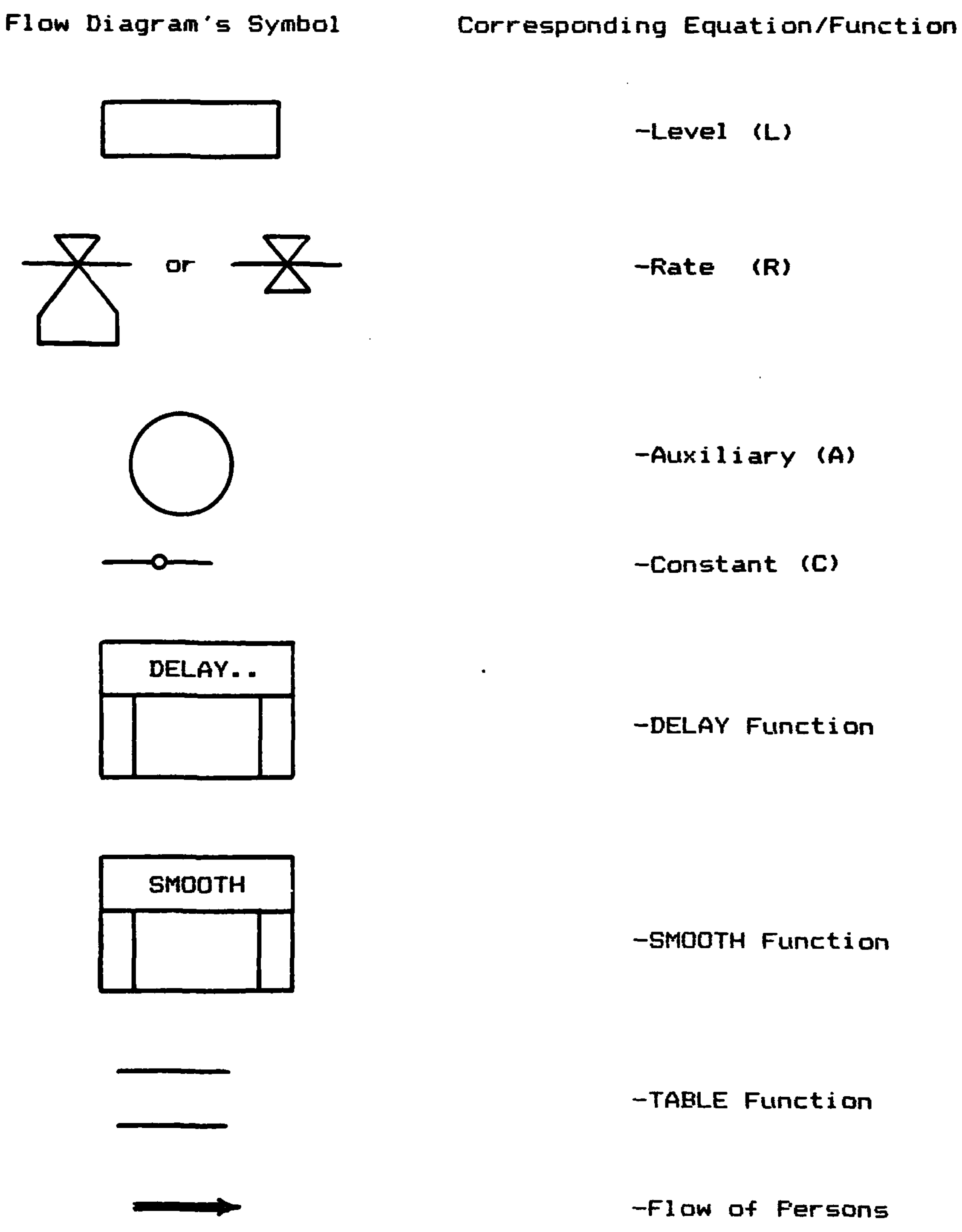


Figure 2.2 Flow Diagram Symbols

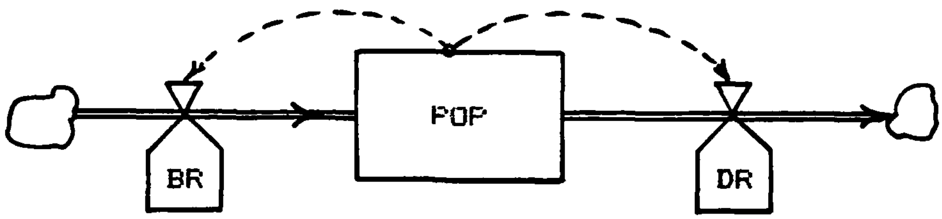


Figure 2.3 Flow Diagram of Interactions of Population, Births, and Deaths

Figure 2.3 depicts the flow diagram corresponding to the causal-loop diagram of the interactions of population, births, and deaths which has introduced before in figure 2.1. The level in this instance is population (POP), as indicated by the rectangular, both births (BR) and deaths (DR) are rates as indicated by the valve symbol. The positive (negative) link from births (deaths) to population in the causal-loop diagram is depicted in the flow diagram as the flow of births into (deaths from) population. The direction of the arrows in the flow diagram indicates that births add to (deaths subtract from) population.

In this study, each variable that will be used in the model is identified in a flow diagram and the connection of arrows pointing to a variable indicate all the elements used in the calculation of the variable.

DYNAMO Equations

Once a flow diagram has been developed, the next step in building a model is to write equations in DYNAMO [1, 30]. DYNAMO is a computer simulation language which used for modeling real-world systems so that their dynamic behavior over time may be traced (imitated, simulated) by a computer. A model written in the language DYNAMO is a view of a feedback system as if it were continuous over time. DYNAMO merely chops up continuous time into discrete bites: one tiny interval of time, then the next. Within each small interval of time, DYNAMO assumes the varying rates are constant and computes like the ordinary algebra. The result is an approximation. If, however, the time between computations (DT) is small enough, and the rates of change not too violent, the computed results will closely match those obtained in closed form by the application of sophisticated mathematics. Variables in DYNAMO have subscripts indicating their place in time. K denotes the present; J the point in time just passed (just preceding K), and L the point of time in the immediate future (immediately following K). The symbol DT is used to represent the length of time elapsed between J and K, or K and L. The value of a level at the present time must equal to its value one time interval earlier, plus whatever flowed into the level over the time interval (minus whatever flowed out).

The population equation in DYNAMO notation thus becomes the following:

```
    L       POP.K=POP.J+DT*(BR.JK-DR.JK)
where
    POP.K = value of population now
    POP.J = value of population a time interval ago
    DT    = length of intervening time
    BR.JK = births per year over the time interval JK
    DR.JK = deaths per year over the time interval JK
```

Six types of DYNAMO equations were used in the model of this study. The equation category is defined by the letter in column one of the model listing. Each of the six types is listed in table 2.1 with a brief definition.

Type	Definition
L	Level equation. Accumulation of quantities flowing in and out of the level
R	Rate equation. Rate of flow of a quantity.
A	Auxiliary equation. Used an intermediate calculation for a rate.
C	Constant. Variable defined to have a constant value for the entire run of the model.
N	Initial value for variable.
T	Table of dependent values used by TABLE function.

Table 2.1 Types of DYNAMO Equations

Using these concepts, the following three sections discuss representation of information flow in System Dynamics models, and modeling changes in information quality attributes.

Information Flow in System Dynamics Models

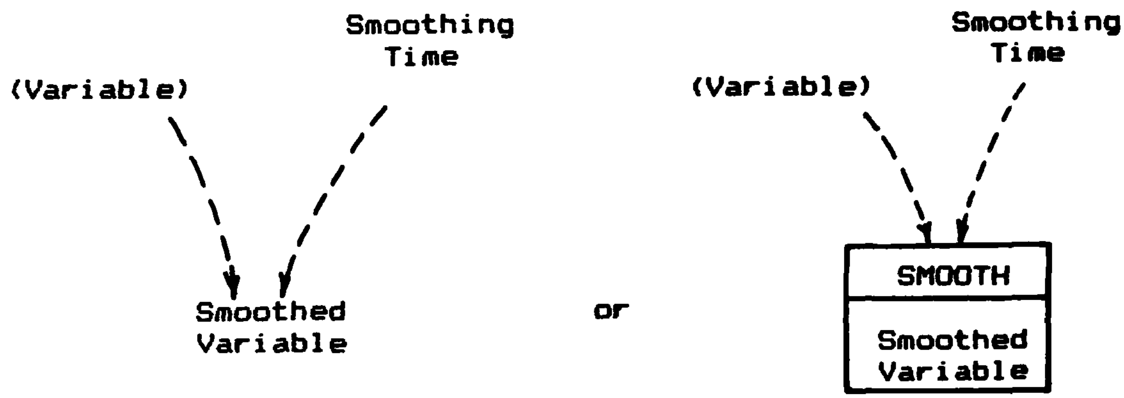
In the structure of a System Dynamics model, information links show the information sources on which the rates depend. "The information links leading to a rate equation do not affect the source levels from which they come, but the flows that are controlled by the rate equation do cause the levels to change." [6:9-1]. A policy (rate equation) governing a rate of flow can be responsive only to the available information at the particular point of policy control in a system. Very often there are distortions in the information network that occur between the "true" levels and the apparent values of those levels. "Information can be delayed. It can be disturbed by random error. It may be biased so that it consistently indicates a displacement from the "true" value. It can be distorted to produce errors that depend on the time-shape of the information stream itself. And it is subject to "cross talk" whereby the information shifts in apparent definition or source. ... Apparent values of information arrive at the policy point, not directly from the "true" level but instead from an

intervening auxiliary equation or information level. An auxiliary equation can insert a simple algebraic variation into the information stream, such as the addition of bias or random error. An intervening information level can introduce time-dependent distortion." [6:9-5]. The following two sections discuss modeling of changes in two information quality attributes, timeliness and accuracy.

Modeling the Timeliness of Information

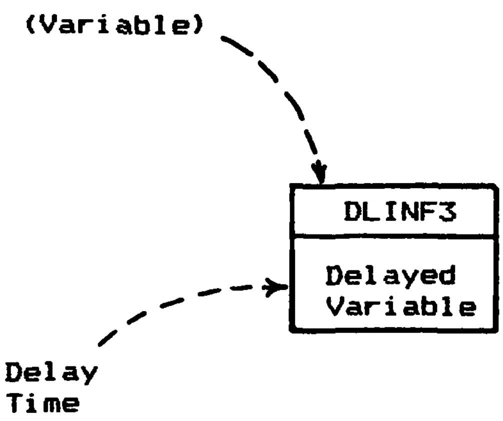
All information used in decision making takes time to collect and compile. The result is that decisions are necessarily based on information which is, to some extent, out of date. The timeliness of information can be modeled by introducing a perception delay into an information flow. The perception delay takes an exponential average of the true information flow, so changes are perceived to occur later than they would otherwise, were instantaneous information available. In DYNAMO language, there are two standard functions to represent information delay which are SMOOTH and DLINF3. SMOOTH function [32:109] represents a first-order information delay; and as the name implies it is also a good function to smooth, or average, a variable. DLINF3 function [32:113] is a third order information delay. The following diagram shows the modeling of both functions and the corresponding DYNAMO statements.

SMOOTH Function:



Smoothed Variable=SMOOTH(Variable,Smoothing time)

DLINF3 Function:



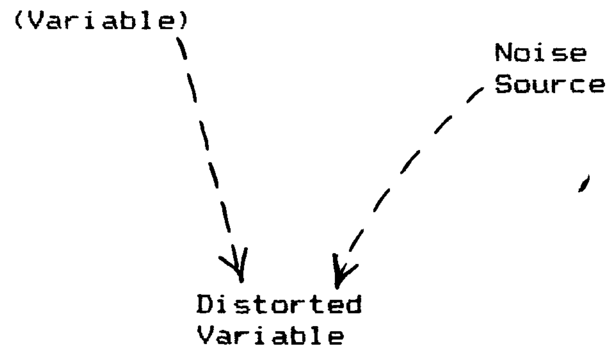
Delayed Variable=DLINF3(Variable,Delay time)

Modeling the timeliness of information is conducted concurrently with modeling the accuracy of information which is discussed in the following section.

Modeling the Accuracy of Information

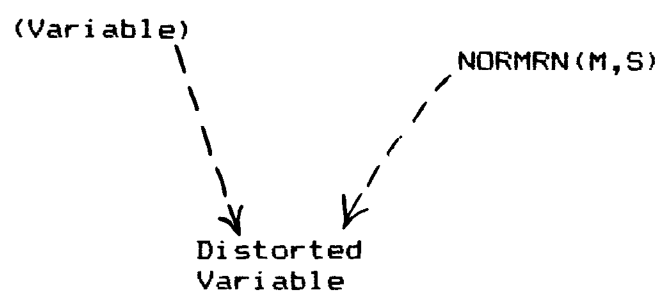
Inaccurate information can be modeled by introducing random variations or bias into an information flow entering a decision. The perceived information flow is defined as the sum of the true information and a random or bias component. The random component is readily obtained using the random number generators of the DYNAMO language [30:28]. There are two standard functions for random number generation which are NOISE and NORMRN. The NOISE function [32:130] provides random numbers distributed uniformly from -0.5 to +0.5, with a mean of zero. Theoretically, the output of the NOISE function should have no relationship between one value and the next (zero autocorrelation). In practice, the relationship is quite small but not ideal. The NORMRN function [30:28] provides random numbers which are nearly normally distributed. The following figure illustrates the modeling of both functions and the corresponding DYNAMO statements.

NOISE Function:



Distorted Variable=F{Variable,NOISE()}
where F is a modeler-made function

NORMRN Function:



Distorted Variable=F{Variable, NORMRN(M,S)};
Where F is a modeler-made function, M is the mean, and S is the standard deviation.

These methods of modeling changes in information quality attributes are used in the next chapter for developing the System Dynamics model of this study.

Summary

In this chapter basic definitions and concepts that will be used throughout the course of the study, are introduced. Definitions and basic concepts of information quality attributes are presented. Causal-loop diagram, flow diagram, and DYNAMO terminology are reviewed as tools of the System Dynamics methodology. The chapter concluded with a discussion of representation of information flow in System Dynamics models, and methods of simulating changes in information quality attributes. Using these definitions and concepts, the model is developed in the following chapter.

III. The Model

Introduction

This chapter presents a brief overview of system structure, the five-year plan of the Egyptian government as a base of the national development process, and the System Dynamics model. The System Dynamics model is developed in three phases. first, a conceptual picture of the primary components of the system is created. Next, the system is divided into five functional sectors (demographic, military, labor, capital, and housing) that were individually developed and tested. Finally, the sectors are integrated and tested as a single unit.

Throughout the three phases of model development, decisions are modeled as a combination of information flows describing the status and objectives of the system. Information entering a decision is assumed to be available with manageable levels of accuracy and timeliness. These levels are changed at the experimentation phase (reported in chapter four) to study the effects of changes in information attributes on the development process. The order of presentation in this chapter follows the phases of development described above.

Overview of System Structure

One method to get a general idea about a system is to compare outputs and inputs of the system [16:241]. In the case of a country, the inputs may be considered the national resources of the country, and the outputs may be represented by the standard of living of the people.

The total area of Egypt is about 386,900 sq.miles (3% cultivated land, 76% potentially fertile desert, 16.9% sandy desert, 0.3% clay desert, 2.5% salty desert, 1.3% islands and lakes) [11]. The river Nile of 1,000 miles flows longitudinally throughout the country and provides from 42 to 150 billion cubic feet per year of rich water (carries about 11 million tons of clay) [25:58]. There are almost 2,000 miles of coastline bordering the Mediterranean, Gulf of Suez, Gulf of Aqaba, and Red Sea. The Suez Canal carries 14% of world seaborne traffic [2]. Almost 50 million tons of oil and natural gases are produced per year [22:295]. Potential tourism of the country covers Pharaonic, Christian, and Islamic eras in addition to the favorable location and climate [11].

Egypt's population [11, 38] has more than quadrupled in 80 years, from 9.7 million at the time of the first census in 1900 to nearly 43 million in 1981. Over 50 percent of which is under the age of 20. A traditional birth rate, coupled with rapidly falling mortality rates resulted in a

natural increase of 2.99 percent per year in 1979. Over 96 percent of the population live on five percent of the country's territory where the density is 1883 per square mile with 44 percent living in urban areas and most of the balance in some 4,000 villages with populations ranging from 500 to 10,000 inhabitants. Cairo, as most urban areas, has a density of over 70,000 person per square mile.

The average life expectancy is about fifty three years and the infant mortality is about 10.1% in 1980. Education is free through university level and under government control. Despite compulsory elementary education, literacy rate is less than 25% in 1975 [25:vii]. At the other end of the scale, nearly half a million students attend the 11 secular universities and other institutions of higher learning. Thus, one out of every 100 Egyptians of all ages is engaged in higher studies [11]. The government insures a job for every graduated. But, comparing their wages with the equivalents in Arab countries enforces a substantial proportion of the labor force to work abroad. The repatriation of remittances from Egyptians working abroad are considered the second source of national income (according to the current governmental five-year plan of national development) [29].

Comparing the outputs, inputs, and rate of growth of the system (figure 3.1) illustrates the level of challenge which faces a plan of national development.

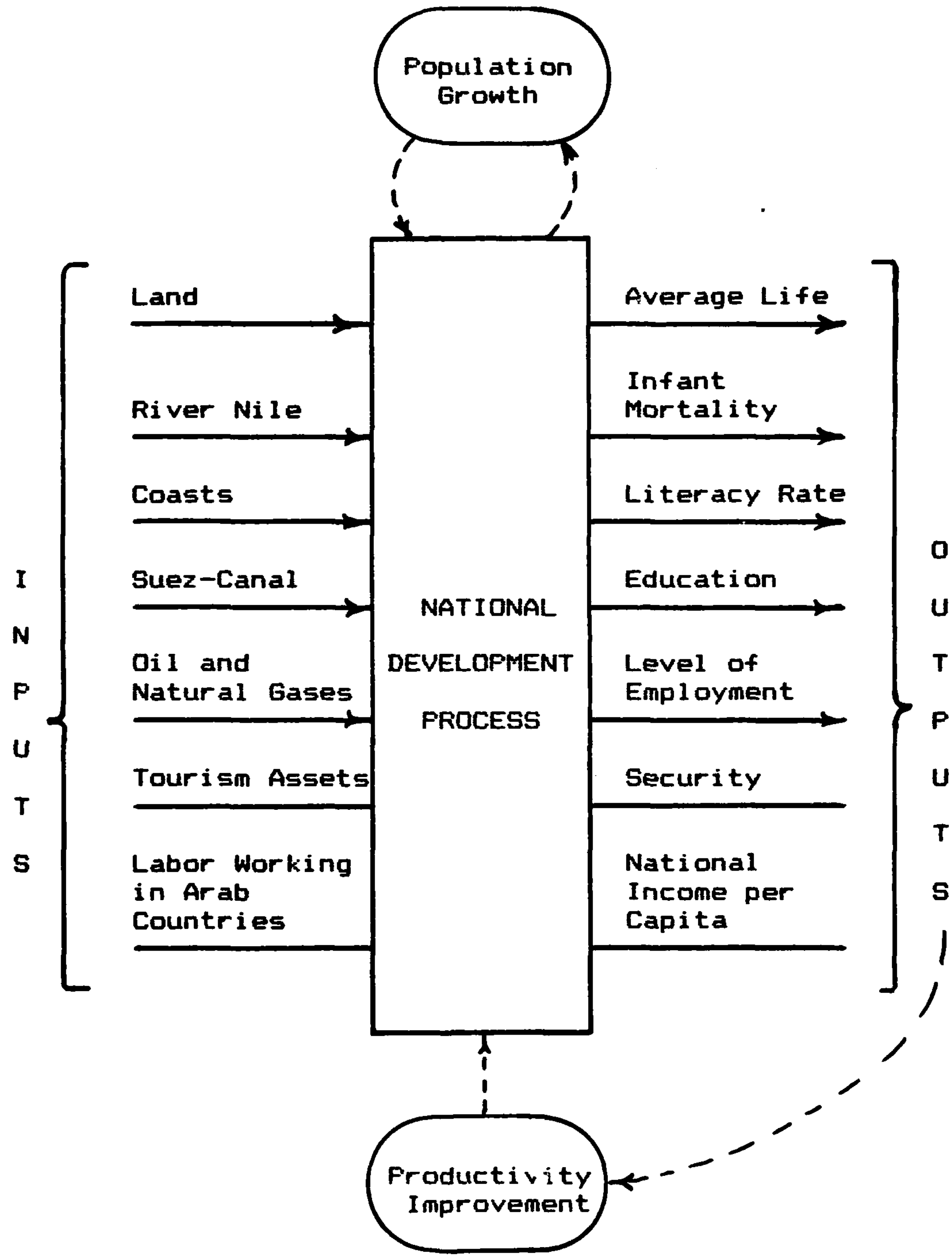


Figure 3.1 A System of National Development

Five-Year Plan of National Development

The five-year plan, covering FY 1982/83 to FY 1987/88, is a detailed document compiled by the ministry of planning [29:4]. It is planned to increase gross national product (GNP) fifty percent over the base period of FY 1981/82, or at an average yearly rate of growth of nine percent in FY 1981/82 prices. Official data indicated that achievement in the first year of the plan, FY 1982/83, was nearly 97 percent of the goal [29:1].

The plan outlines four objectives to achieve. First, increasing the investment rate to achieve full employment. Full employment is defined as "a situation where every one who wants to work at the prevailing wage rate can fined a job in the line of work for which he or she is qualified." [27:408]. Second, achieving the balance between the production and consumption by increasing the output of the production sector nine percent per year. Third, keeping the armed forces on the same level of manpower while acquiring more sophisticated weapons. Fourth, improving the standard of living by increasing the family consumption by a rate equal to double the rate of growth of population, increasing the public consumption (public services) with a rate of 7.9% per year, and constructing 160,000 housing unit per year [29:1-10].

Conceptual Structure of the Model

The five-year plan mentioned in the above section represents the basic trends of the government policy for the national development. In this research, the System Dynamics model of the national development process is built on a time horizon equal to sixty years. The time horizon, or time frame, is defined as "the period of time over which the problem plays itself out." [32:21]. Sixty years is considered enough time to depict the results of a national policy of development as adopted by most national economic models [13]. Specifying the time horizon leads to the appropriate causal relationships which have to be considered in the model.

The causal relationships between the main factors of national development are illustrated in figure 3.2. Two of those factors are common in any development process which are the workforce and capital [35:773]. Both of those two factors, through a given production function, lead to more production which increases national income. As the national income increases, it permits more investments in social and capital sectors which lead to an increase in the work force and the capital. For a certain national income, the increase in social investments causes a decrease in capital investments and vice versa. In Egypt, particularly, a significant portion of the workforce goes abroad to work in

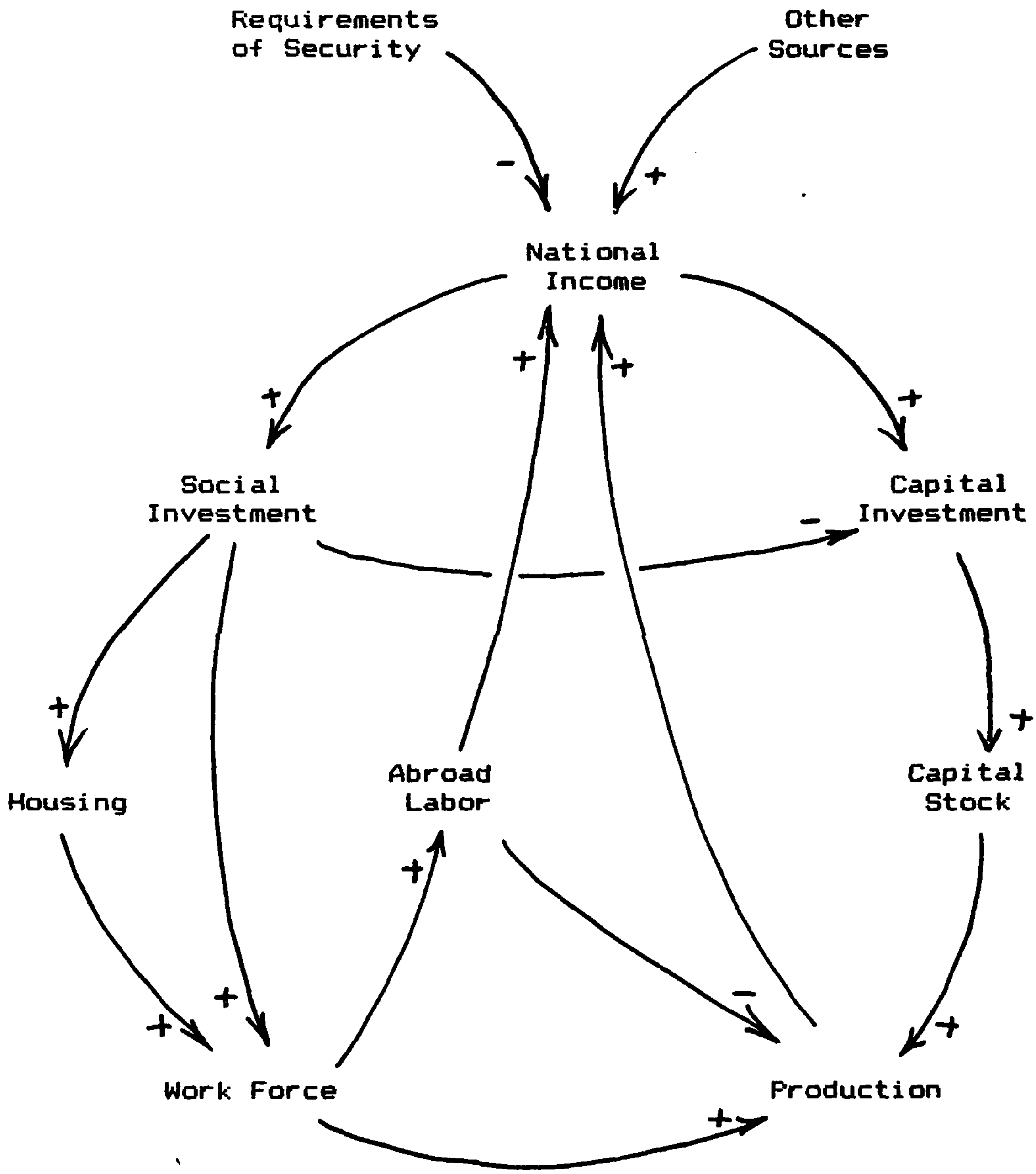


Figure 3.2 Comprehensive Causal-Loop Diagram of the National Development Process.

other Arab countries. This contributes to raising the national income but may cause a decrease in the national production. A housing shortage is considered one of the largest national problems and receives special attention as a part of the development process.

The system of national development is divided into five sectors which are demographic (DS), military (MS), labor (LS), capital (CS), and housing (HS). Those sectors represent the main concerns of the development plan. The following five sections describe, discuss, and formulate the main variables considered in each sector.

Demographic Sector

The demographic sector includes the major variables for population and education. This sector is considered as the basic source and ultimate objective of the development process. Population with higher level of education, health, and productive life (high average-life expectancy or low death rate) implies more work force and higher level of productivity. This, in turn, implies more production and more national income. On the other side, increasing of population with insufficient national income implies decreasing of consumption, education, and public services per capita.

Figure 3.3 depicts the main causal-loops of this sector.

The main variables that control the population are the birth rate and death rate. Immigration movement has no significant effect on the population of Egypt [38]. The birth rate is affected mainly by education ratio which depends on education expenditure per capita. This expenditure decreases as the school-age population increases. In Egypt, like most developing countries, the death rate depends mainly on average consumption per capita which is expected to be decreased as the population increases. As illustrated in figure 3.3, the birth-rate loop has a positive polarity (even number of negative signs) which means that it tends to destablize the system; and the death-rate loop has a negative polarity which means that it controls the population. As the population increases, the adult population, work force, production, and national income will be sequentially increased. As the national income increases, consumption, education, and public services per capita are increased. On the other hand, as the population increases, the public services per capita, productive life, and work force are sequentially decreased.

Figure 3.4 depicts the corresponding flow diagram of the demographic sector. The population is divided into three age groups: school age population (SAPOP) which are the children from six up to eighteen, adult population (ADPOP) which are the people from eighteen up to a retirement age, and total population.

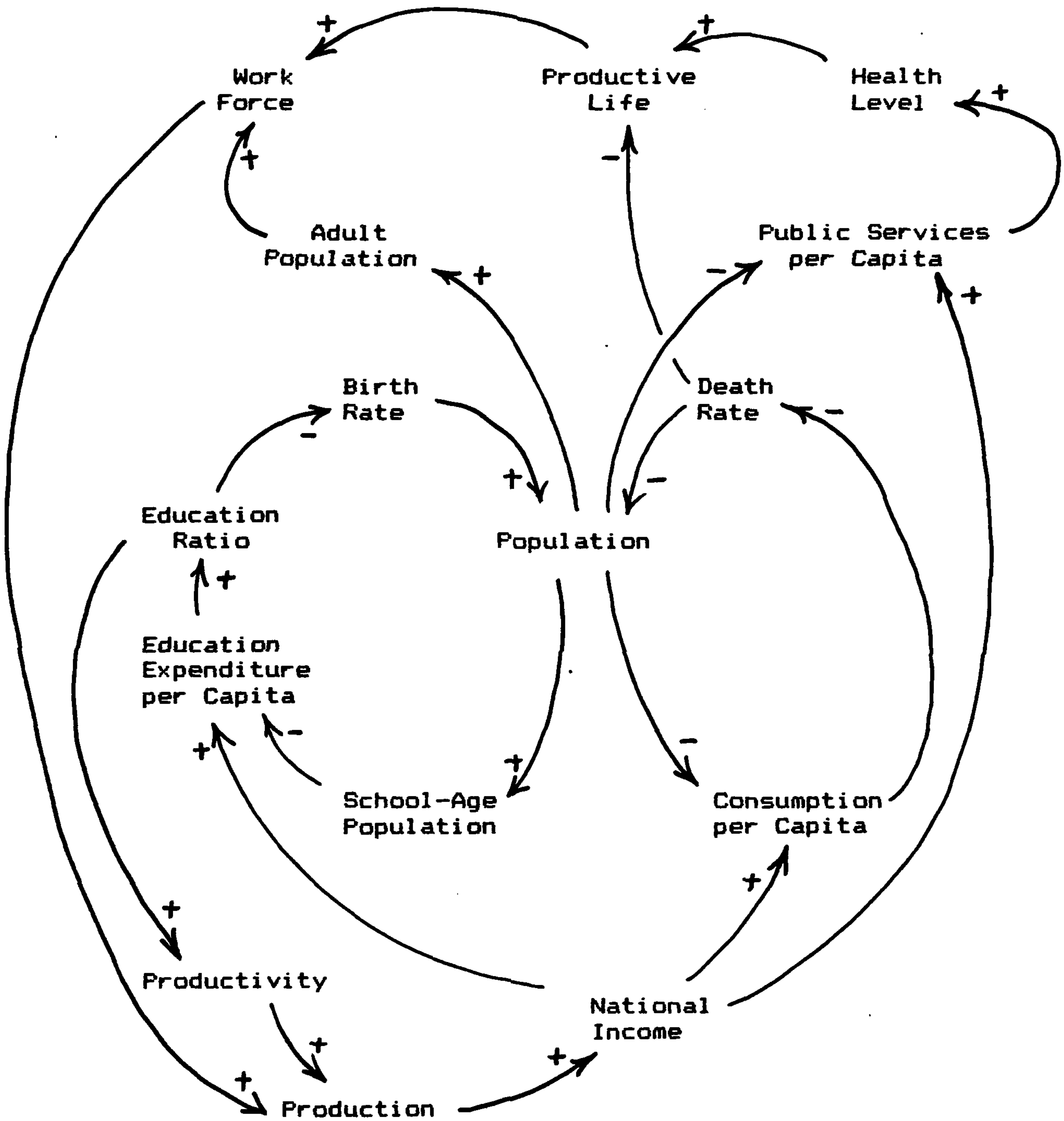


Figure 3.3 Causal-Loop Diagram of the Demographic Sector

The birth rate (BR) depends on the number of adults and the birth rate fraction (BRF) which depends on the education ratio (EDRT). The death rate (DR) depends on the total population and the death rate fraction (DRF) which depends on the consumption level per capita (CNS1). The average productive life (APL), which is the difference between the adult access age and the retirement age, depends on the death rate fraction and a health level multiplier (HLF). The later depends on the public service expenditure per capita (PSEX1) as a measure of health care. The education level is a smoothed value of the ratio of school-age population (SAPOP) who attend schools. It equals to education expenditure per pupil (EDEX1) divided by the annual cost of education per pupil (EDC). The education process has to be adjusted to match the professional requirements of different jobs. The adjusted education ratio (AERT) depends upon the quality of information received from the job market. The quality of information is represented by a noise function which applied on a portion of the education level (PRCH). This portion represent the rate of technological change. The increase in total population decreases the per capita expenditures (CNS1, EDEX1, and PSEX1).

As the society increases its education level the birth rate can be expected to decrease. From official information

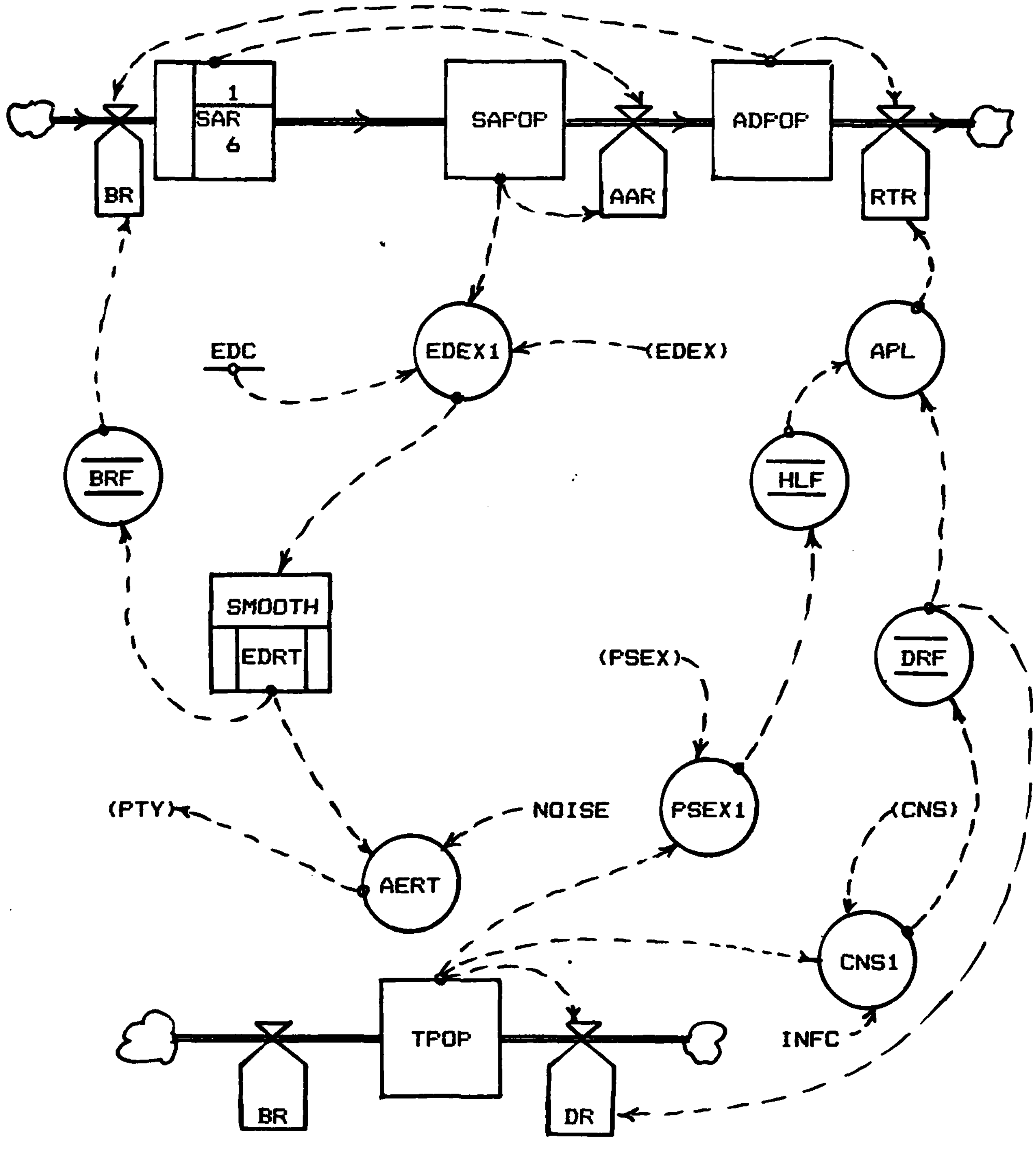
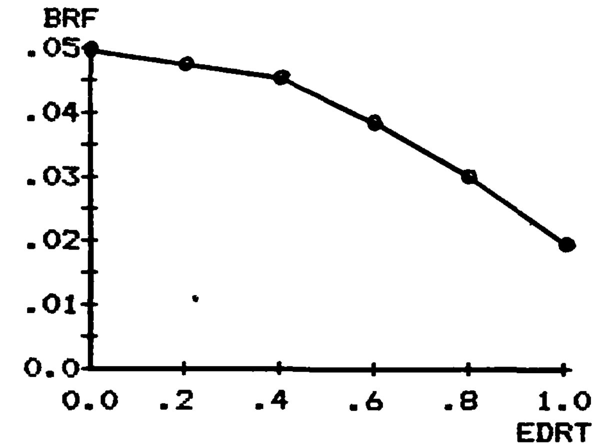
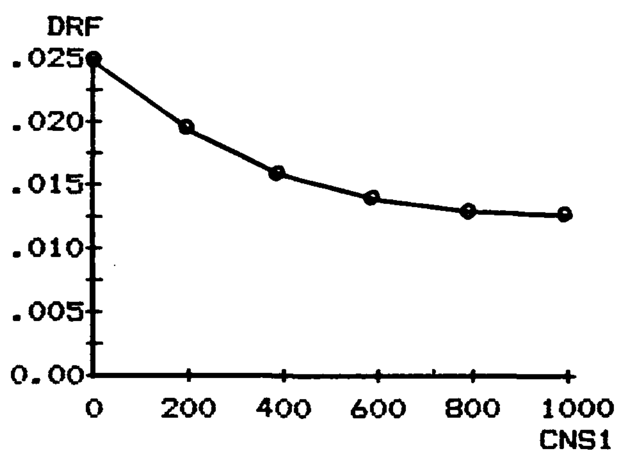


Figure 3.4 Flow Diagram of the Demographic Sector



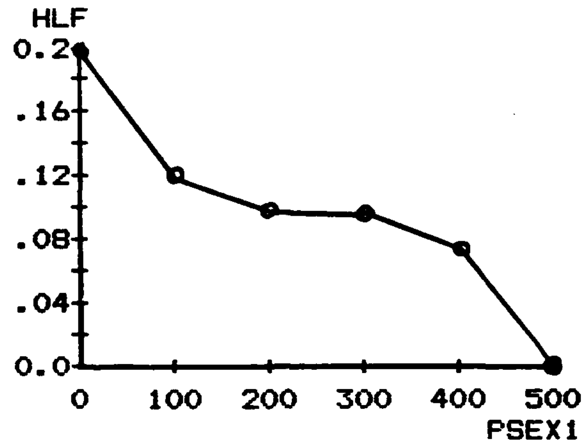
Education Ratio (EDRT)	0.0	0.2	0.4	0.6	0.8	1.0
Birth Rate Fraction (BRF)	.05	.048	.046	.038	.030	.02

Figure 3.5 Table Function of Birth Rate Fraction



Consumption per Capita (CNS1)	0	200	400	600	800	1000
Death Rate Fraction (DRF)	.025	.019	.016	.0145	.0135	.013

Figure 3.6 Table Function of Death Rate Fraction



Public Service Expenditure per Capita (PSEX1)	0	100	200	300	400	500
Health Factor (HLF)	.20	.12	.10	.10	.08	0.0

Figure 3.7 Table Function of Health Factor

published about the birth rate fraction and the education level in the years 1960-1980 [38], a table function of the birth rate fraction is developed (figure 3.5).

As the level of consumption in a developing country raises, the death rate can be expected to decrease. From the same source of data a table function of the death rate fraction is developed (figure 3.6).

As the public services expenditure increases (a measure of health care increasing), the multiplier on the average productive life (HLF) can be expected to increase. Figure 3.7 includes a table function which depicts this relationship.

The following is the DYNAMO formulation and data dictionary of the school-age population level.

```
L    SAPOP.K=SAPOP.J+(DT)(SAR.JK-AAR.JK)             DS1
N    SAPOP=12.2                                       DS2
R    SAR.KL=DELAY1(BR.JK,6)                           DS3
R    BR.KL=(ADPOP.K)(BRF.K)                           DS4
A    BRF.K=TABLE(TBRF,EDRT.K,0,100,20)                DS5
T    TBRF=.05/.048/.046/.038/.030/.02
R    AAR.KL=DELAY1(SAR.JK,12)                         DS6
A    EDRT.K=SMOOTH(SCRT.K,12)                         DS7
A    SCRT.K=MIN(EDEX1.K/EDC,99)                       DS8
A    EDEX1.K=EDEX.K/SAPOP.K                           DS9
A    RPRCH.K=EDRT.K*((1-PRCH)+PRCH*NOISE())           DS10
A    AERT.K=DLINF3(RPRCH.K,4)                         DS11
A    EDEX.K=GOT.K*EDP                                 DS12
C    EDP=0.2                                          DS13
C    EDC=0.65                                         DS14
```

```
AAR    = Access Rate of Adult Population
                                          (person per year)
ADPOP  = Adult Population                          (person)
AERT   = Adjusted Education Ratio        (dimensionless)
BR     = Birth Rate                       (person per year)
BRF    = Birth Rate Fraction            (Fraction per year)
EDC    = Education Cost             ($ per pupil per year)
EDEX   = Education Expenditure                ($ per year)
EDEX1  = Education Expenditure per pupil
                                    ($ per pupil per year)
EDP    = Priority of Education           (dimensionless)
EDRT   = Education Ratio                 (dimensionless)
GOT    = Government Social Expenditure        ($ per year)
PRCH   = Rate of Technological Change    (dimensionless)
RPRCH  = Preceived Rate of Technological
                          Change         (dimensionless)
SAPOP  = School-Age Population                    (person)
SAR    = Access Rate of School-Age Population
                                          (person per year)
SCRT   = Ratio of Children Attend Schools
                                         (dimensionless)
```

The following is the DYNAMO formulation and data dictionary of the adult population level.

```
L    ADPOP.K=ADPOP.J+(DT)(AAR.JK-RTR.JK)             DS15
N    ADPOP=22                                         DS16
R    RTR.KL=ADPOP.K/APL.K                             DS17
A    APL.K=(1/DRF.K-18)(1-HLF.K)                      DS18
A    HLF.K=TABLE(THLF,PSEX1.K,0,500,100)              DS19
T    THLF=.20/.12/.10/.10/.08/0.0
A    PSEX1.K=PSEX.K/TPOP.K                            DS20
```

```
A     PSEX.K=GOT.K*PSP                                     DS21
C     PSP=0.5                                              DS22

APL   = Average Productive Life                         (years)
DRF   = Death Rate Fraction             (fraction per year)
HLF   = Health Factor                       (dimensionless)
PSEX  = Public Service Expenditure              ($ per year)
PSEX1 = Public Service per Capita
                                    ($ per person per year)
PSP   = Priority of Public Services    (dimensionless)
RTR   = Retirement Rate                   (person per year)
TPOP  = Total Population                           (person)
```

The following is the DYNAMO formulation and data dictionary of the total population level.

```
L     TPOP.K=TPOP.J+(DT)(BR.JK-DR.JK)                      DS23
N     TPOP=46                                              DS24
R     DR.KL=(TPOP.K)(DRF.K)                                DS25
A     DRF.K=TABLE(TDRF,CNS1.K,0,1000,200)                  DS26
T     TDRF=.025/.019/.016/.0145/.0135/.013
A     CNS1.K=CNS.JK*INFC/TPOP.K                            DS27

CNS  = Consumption                              ($ per year)
CNS1 = Rate of Consumption per Capita
                                    ($ per person per year)
DR   = Death Rate                         (person per year)
INFC = Information Completeness             (dimensionless)
```

The demographic sector has a direct interaction with the military sector which is introduced in the following section.

Military Sector

The military sector consists of two main components, weapon systems and manpower. The expenditure of acquiring and maintaining sophisticated weapon systems is a vital portion of the national expenditure for which a certain percentage of the gross national income is devoted.

Throughout this research the national income is considered as the net income after deduction of the weapon system duties, so, the military sector will be treated from the manpower point of view. The manpower in the military sector is divided into two categories, professionals and draftees. The professionals are the officers, noncommissioned officers, and civilians who are working for the military sector most of their productive life. The draftees are men recruited to serve in the military for a certain period, two years in average, known as mandatory service. The mandatory service can be completely productive or start with a training period (six months) followed by a productive one according to recorded past experience. If there are complete and relevant information about the preceding experience of draftees, the training period and effort (cost) will be reduced. In the model, the draftees who do not need training is equal to the draftees who have experience multiplied by information completeness factor.

Figure 3.8 illustrates a flow diagram of the manpower in the military sector. Three levels are considered in this sector, the number of professionals (VMF), draftees under training (DAT), and productive draftees (DUS). According to the hierarchy in the military-sector construction, the ratio (VDR) between professionals (VMF) and draftees (DUS) is maintained as one forth. AVF, the rate of access to the first level (VMF) depends on the level (VMF), the

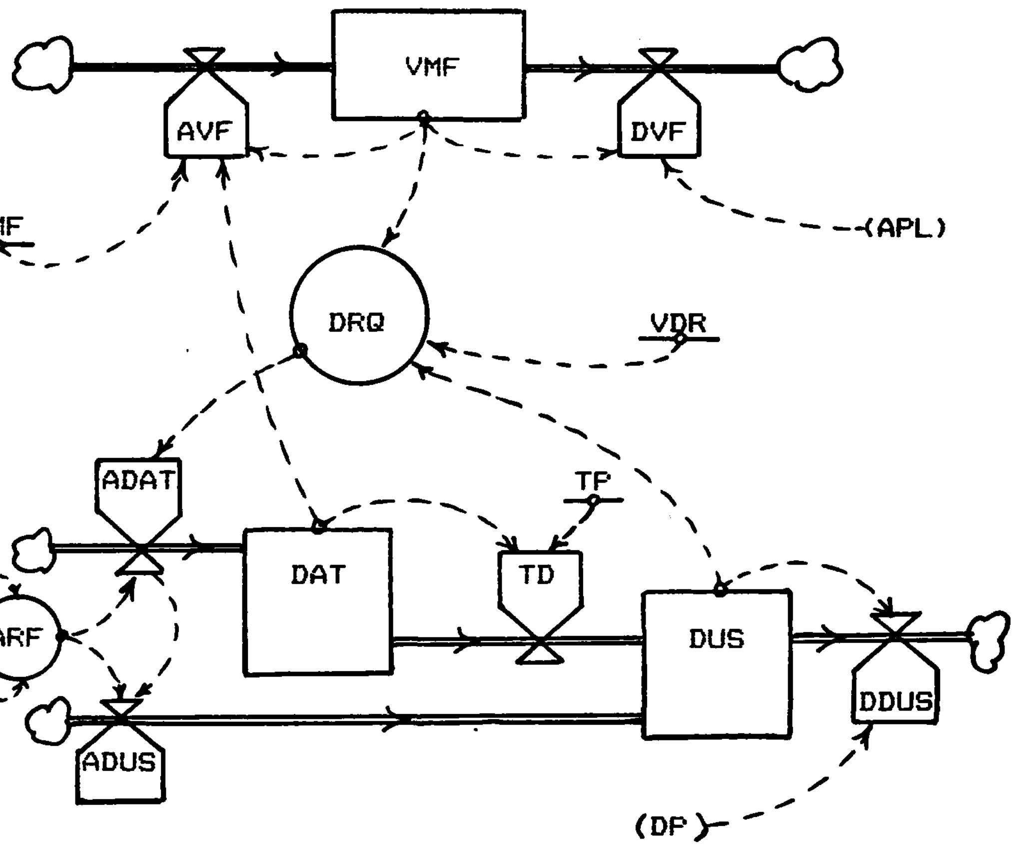


Figure 3.8 Flow Diagram of the Military Sector

anticipated level which is one fifth of the total required military force (TMF), and the professionals required to train the draftees (estimated as 1/100 of the draftees level). DVF, the rate of departure from the level (VMF) depends on the level (VMF) and the average productive life (APL). ADAT, the rate of access to the second level (DAT) depends on the draftees required (DRQ), which are four times the level (VMF), the level of productive draftees (DUS), and

the recorded fraction of draftees who do not need training (ARF). TD, the departure from the level of draftees under training (DAT) depends on the level (DAT) and the period of training (TP). ADUS, the access to the level (DUS) is the ratio of draftees who do not need training which is equal to the rate (ADAT) multiplied by (1-ARF/ARF). DDUS, the departure rate from the level (DUS) depends on the mandatory service period (DP) and the levels (DUS) and (DAT). The fraction (ARF) depends on the adjusted education ratio, the information completeness, and the portion of military training that could be replaced. This portion is estimated as 10% of the military training.

The DYNAMO formulation and data dictionary of this sector is listed below.

```
L    VMF.K=VMF.K+(DT)(AVF.JK-DVF.JK)            MS1
N    VMF=TMF*VDR                                MS2
R    DVF.KL=VMF.K/APL.K                         MS3
R    AVF.KL=(TMF*VDR)+(0.01*DAT.K)-VMF.K        MS4
L    DUS.K=DUS.J+(DT)(ADUS.JK+TD.JK-
X      DDUS.JK)                                 MS5
N    DUS=0.75*TMF*(1-VDR)                       MS6
R    DDUS.KL=(DUS.K+DAT.K)/DP                   MS7
R    ADUS.KL=DRQ.K*ARF.K                        MS8
A    DRQ.K=(VMF.K/VDR)-DUS.K                    MS9
L    DAT.K=DAT.J+(DT)(ADAT.JK-TD.JK)            MS10
N    DAT=0.25*TMF(1-VDR)                        MS11
R    TD.KL=DAT.K/TP                             MS12
R    ADAT.KL=DRQ.K*(1-ARF.K)                    MS13
A    ARF.K=AERT.K*NRMRN(USMN,0.1)/1000          MS14
C    VDR=.25                                    MS15
C    TMF=0.5                                    MS16
C    TP=0.5                                     MS17
C    DP=2                                       MS18
```

ADAT = Rate of Access to Draftees Under Training (person per year)

ADUS = Rate of Access to Productive Draftees

(person per year)

ARF = Fraction of Draftees Who Do Not Need Training (dimensionless)

AVF = Rate of Access of Professionals (person per year)

DAT = Draftees Under Training (person)

DDUS = Rate of Departure of Draftees (person per year)

DP = Draft Service Period (year)

DUS = Productive Draftees (person)

DVF = Rate of Retirement of Professionals (person per year)

TD = Rate of Departure of Draftees Under Training (person per year)

TMF = Anticipated Total Military Force (person)

TP = Training Period (year)

USMN = Allocation Factor (dimensionless)

VDR = Ratio of Professional (dimensionless)

VMF = Professionals (person)

Both the demographic and military sectors are considered the basic source of manpower to the labor sector, which is discussed in the following section.

Labor Sector

The labor sector includes both labor working inside and outside the country. One of the main features of the Egyptian economy is that a portion of the national income comes from the revenue of the Egyptian labors working in other Arab countries. Figure 3.9 depicts main causal-loops of the labor sector. The available labor (without jobs) provides the required domestic labor; and as the domestic labor increases, the available labor will be decreased. Because the domestic labor is the main source of the labor working abroad, the increase in the abroad labor decreases the domestic labor.

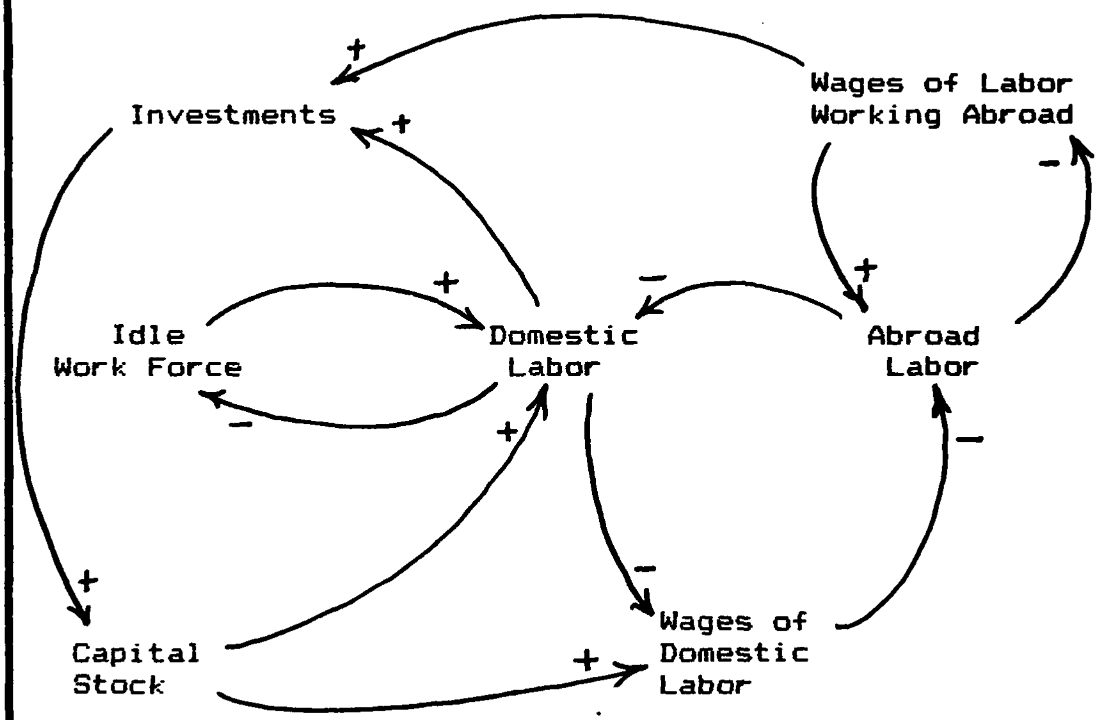


Figure 3.9 Causal-Loop Diagram of Labor Sector

As the abroad labor increases, their wages are decreased and vice versa. Increasing the domestic labor increases production, investments, and capital stock. Increasing the capital stock increases both the domestic labor and wages. A part of the wages of labor working abroad is devoted to investments inside the country.

Figure 3.10 includes the corresponding flow diagram of the labor sector. The sector consists of the labor working

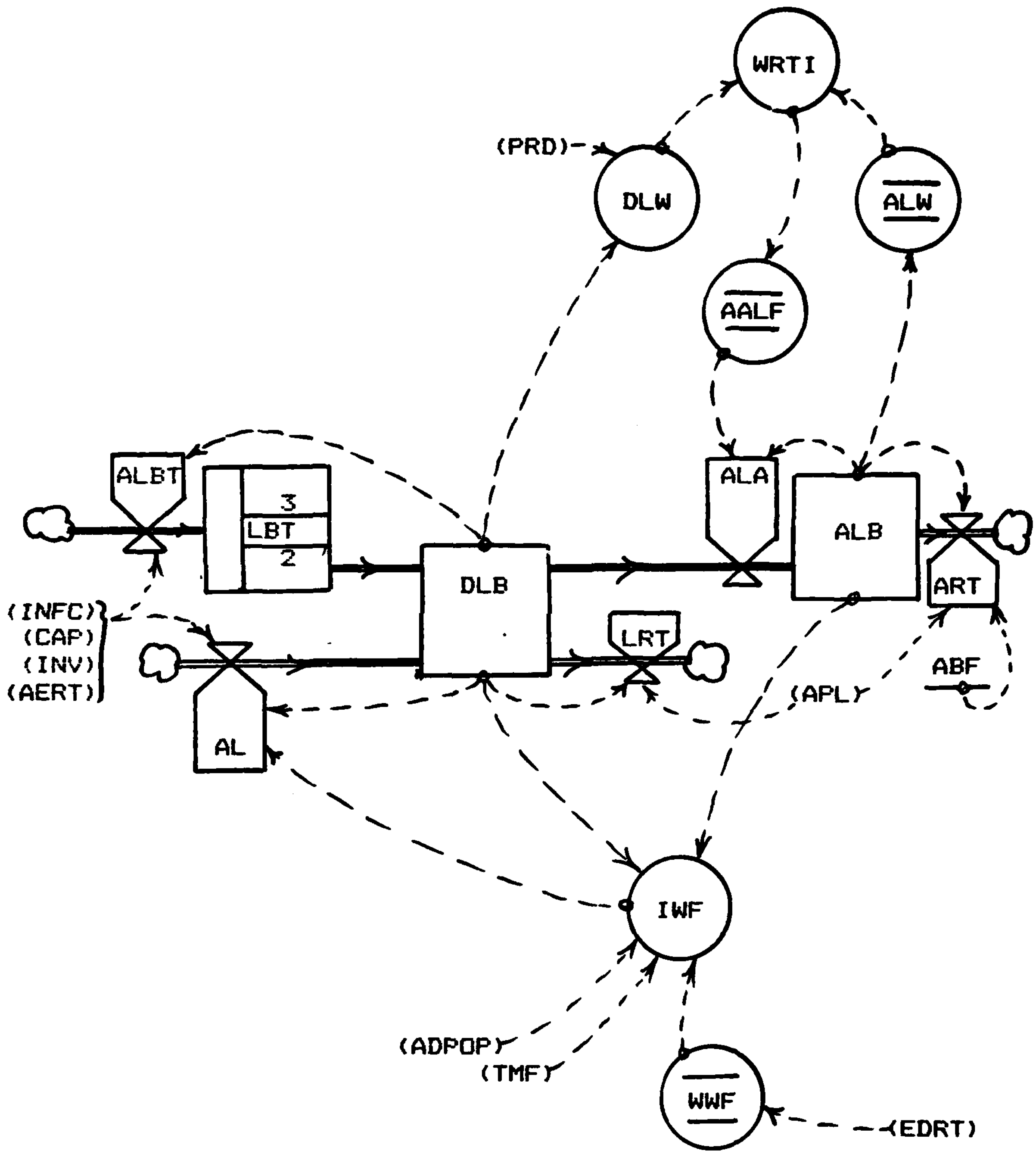


Figure 3.10 Flow Diagram of the Labor Sector

inside the country, which is represented by the level (DLB), and the labor working outside, which is represented by the level (ALB). As development in the capital sector lags behind development in the social sector, the wages and the available jobs decrease and the rate of access to the labor works abroad (AAL) increases causing the number of labor working abroad to be increased. As the number of labor working abroad increases, the wages of abroad jobs (ALW) decreases which, in turn, decreases the rate (AAL).

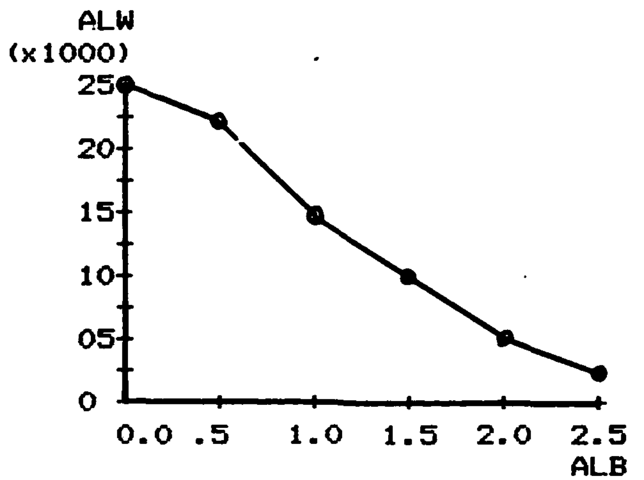
Considering the minimum wage laws, the wages of domestic labor (DLW) depends on the production and the labor involved in the production process. The hiring rate for domestic labor (AL) depends on the level of domestic labor (DLB), the number of available labor who have no jobs (IWF), and a multiplier from the ratio between the investment (CS14) and the capital stock (CS21).

The departure rate from the level of domestic labor (LRT) depends on the level (DLB) and the average productive life of labor (APL). The departure rate from the level of abroad labor (ART) depends on the average productive life (APL) multiplied by an abroad factor (ABF) represents the effects of working abroad on the productive life of the worker. This factor is estimated at 0.8 through interviews.

The flow to the level of domestic labor (DLB) comes directly through a rate (AL) for people with recorded previous experience, or through a training period (averaged

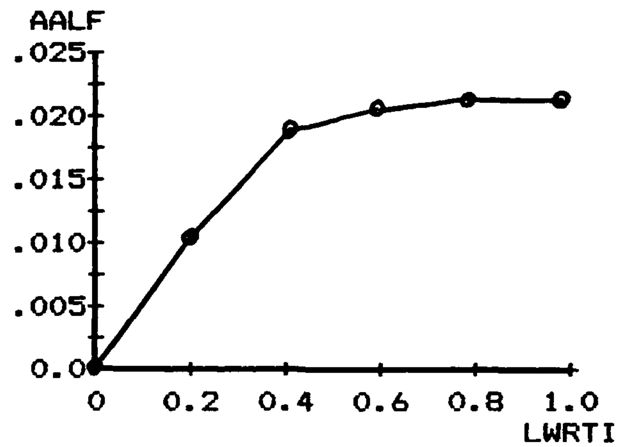
two years) with a delayed rate (ALBT) for the people without recorded previous experience. The rate (ALBT) depends on the rate of access to adult population (AAR) which is mentioned in the population sector (DS6) multiplied by a factor (WWF) representing the fraction of women who do not work which in turn depends on the level of education (EDRT). The labor sector affected by the education adjustment mentioned in the expanded demographic sector and by the quality of information exchanged with the military sector about the allocation of people on the same field of experience. The ratio of expert labor depends on the adjustment factor of education and the quality of information exchanged with the military sector.

Through an interview with researchers related to the field, the empirical relationship between the number of abroad labor (ALB) and the wages of abroad jobs (ALW) is estimated and represented in figure 3.11. Also, the relation between the abroad-labor access factor, domestic wages, and abroad wages is estimated and presented as a table function in figure 3.12. The relation between the education ratio and working women is estimated and presented in figure 3.13.



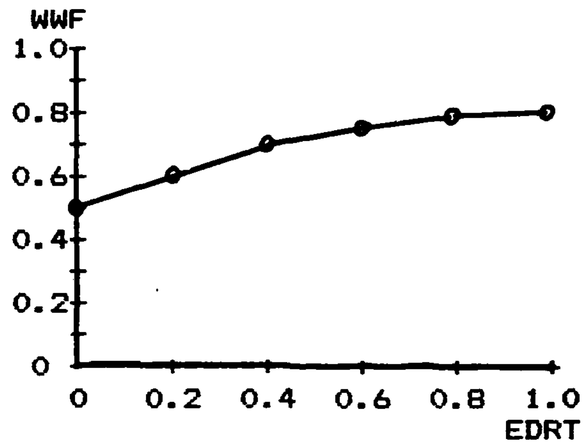
Labor Working Abroad (ALB)	0.0	0.5	1.0	1.5	2.0	2.5
Wages (ALW)x1000	25	23	15	10	5	2.5

Figure 3.11 Table Function of Wages of Abroad Labor



Ratio of Wages Difference (LWRTI)	0.0	0.2	0.4	0.6	0.8	1.0
Access Factor of Abroad Labor (AALF)	0.0	.01	.018	.02	.021	.021

Figure 3.12 Table Function of
Access Factor of Abroad Labor



Education Ratio (EDRT)	0.0	0.2	0.4	0.6	0.8	1.0
Women-Working Factor (WWF)	0.5	0.6	0.68	0.74	0.78	0.80

Figure 3.13 Table Function of Women-Working Factor

The DYNAMO program and data dictionary for this sector are listed bellow.

```
L   DLB.K=DLB.J+(DT)(AL.JK+LBT.JK-
X     RL.JK-AAL.JK)                              LS1
N   DLB=11                                       LS2
R   RL.KL=DLB.K/APL.K                            LS3
R   AL.KL=MIN(DLB.K*INFC*INV.JK/CAP.K,IWF.K)     LS4
R   LBT.KL=DELAY3(ALBT,2)                        LS5
A   ALBT.KL=DLB.K*(1-INFC)*INV.JK/CAP.K          LS6
A   IWF.K=MAX(ADPOP.K*WWF-DLB.K-ALB.K-
X     DAT.K-DUS.K,0.0)                           LS7
A   WWF.K=TABLE(TWWF,EDRT.K,0,1,0.2)             LS8
T   TWWF=0.5/0.6/0.68/0.74/0.78/0.80
A   ALW.K=TABLE(TALW,ALB.K,0,2.5,0.5)            LS9
T   TALW=25000/23000/15000/10000/5000/2500
R   AAL.KL=ALB.K*AALF.K                          LS10
A   AALF.K=TABLE(TAALF,LWRTI.K,0,1,0.2)          LS11
T   TAALF=0.0/.01/.018/.02/.021/.021
A   LWRTI.K=(ALW.K-DLW.K*5)/ALW.K                LS12
A   DLW.K=MAX(PRD.JK/5/DLB.K,500)                LS13
L   ALB.K=ALB.J+(DT)(AAL.JK-RAL.JK)              LS14
N   ALB=1                                        LS15
```

R RAL.KL=ALB.K/APL.K/ABF LS16
C ABF=0.8 LS17

AAL = Access Rate of Abroad Labor (person per year)
AALF = Access Rate Fraction of Abroad Labor (dimensionless)
ABF = Fraction of Retirement of Abroad Labor (dimensionless)
AL = Access of Domestic Labor (person per year)
ALB = Labor Working Abroad (person)
ALBT = Access Rate of Labor Needs Training (person per year)
ALW = Wages of Abroad Labor ($ per person per year)
DLB = Domestic Labor (person)
DLW = Wages of Domestic Labor ($ per person per year)
IWF = Idle Work Force (person)
LBT = Rate of Training of Labor (person per year)
LWRTI= Ratio of Differences of Wages (dimensionless)
RAL = Retiring Rate of Abroad Labor (person per year)
RL = Retiring Rate of Domestic Labor (person per year)
WWF = Fraction of Woman Working (dimensionless)

Capital Sector

In Egypt, the national income can be measured by its three main expenditure components: consumption, investment, and government expenditure [27:410]. Also it can be measured by its two main income components: production and other financial resources such as oil, Suez Canal, tourists, and taxes. Figure 3.14 is a flow diagram of this sector. The accumulated national income is represented by a level (ANI) which has investments (INV), consumption (CNS), and government expenditures (GEX) as outputs rates: and has

production (PRD) and other financial resources (OTI) as input rates. Investment rate (INV) depends on the accumulated national income (ANI) and the tax ratio (TXRT) which depends on the idle work force through a multiplier (MIWF). The consumption rate (CNS) depends on the production rate and a minimum level of consumption (MCNS). There is a subsidization program which assures a minimum level of consumption. This level depends on the effectiveness of the distribution process, which in turn depends on the quality of information (INFC). The government expenditure rate (GEX) depends on military expenditures and the governmental policy of funds allocation to public services, education, houses, and new communities. The production rate (PRD) depends on the capital stock (CAP), the domestic labor (DLB), and the productivity (PTY) through a Cobb-Doglass function [35:736]. The rate of the other financial resources (OTI) depends on tourist revenue (TRR), Suez Canal revenue (SCR), oil revenue (OLR), abroad labor revenue (ALB), and taxes revenue (TXRV). The tourist revenue depends on the population density (POPDN). Both Suez Canal and oil revenues are assumed to be dependent upon time (equations C57 and C58). Abroad labor revenue depends on the level of abroad labor (ALB) and the wages of abroad labor (ALBW). the tax revenue (TXRV) depends on the tax ratio and the capital stock. Although the ratio of taxes collected measured against the tax potential of the economy

is considered one of the highest ratios in the developing countries [25:260], some analysts think that this ratio will increase significantly if there is effective unified information system capable to record, check, and match different business activities. The ineffective collection of taxes forces the government to assign higher tax ratio which, in turn, affects the rate of investment.

The investment rate controls the flow from the accumulated national income to a level of capital stock (CAP). The rate of departure (CDR) from the level of capital stock (CAP) depends on the level of (CAP) and an average life of capital (ALC).

To represent the loans mechanism in the national economy, a level of available loans (LNS) is added to the sector. This level is considered of initial value (ILNS). The difference between the initial value (ILNS) and a current value (LNS) represents the actual loans received by the government up to this time. According to that difference and a certain period of loan returning (RTI), a loans returning rate (LNSR) is established to control the flow from the accumulated national income level (ANI) to the loans level (LNS). The rate of access of loans to the accumulated national income (LNSA) depends on the level of accumulated national income (ANI) and a minimum permissible level of the accumulated national income (MNI).

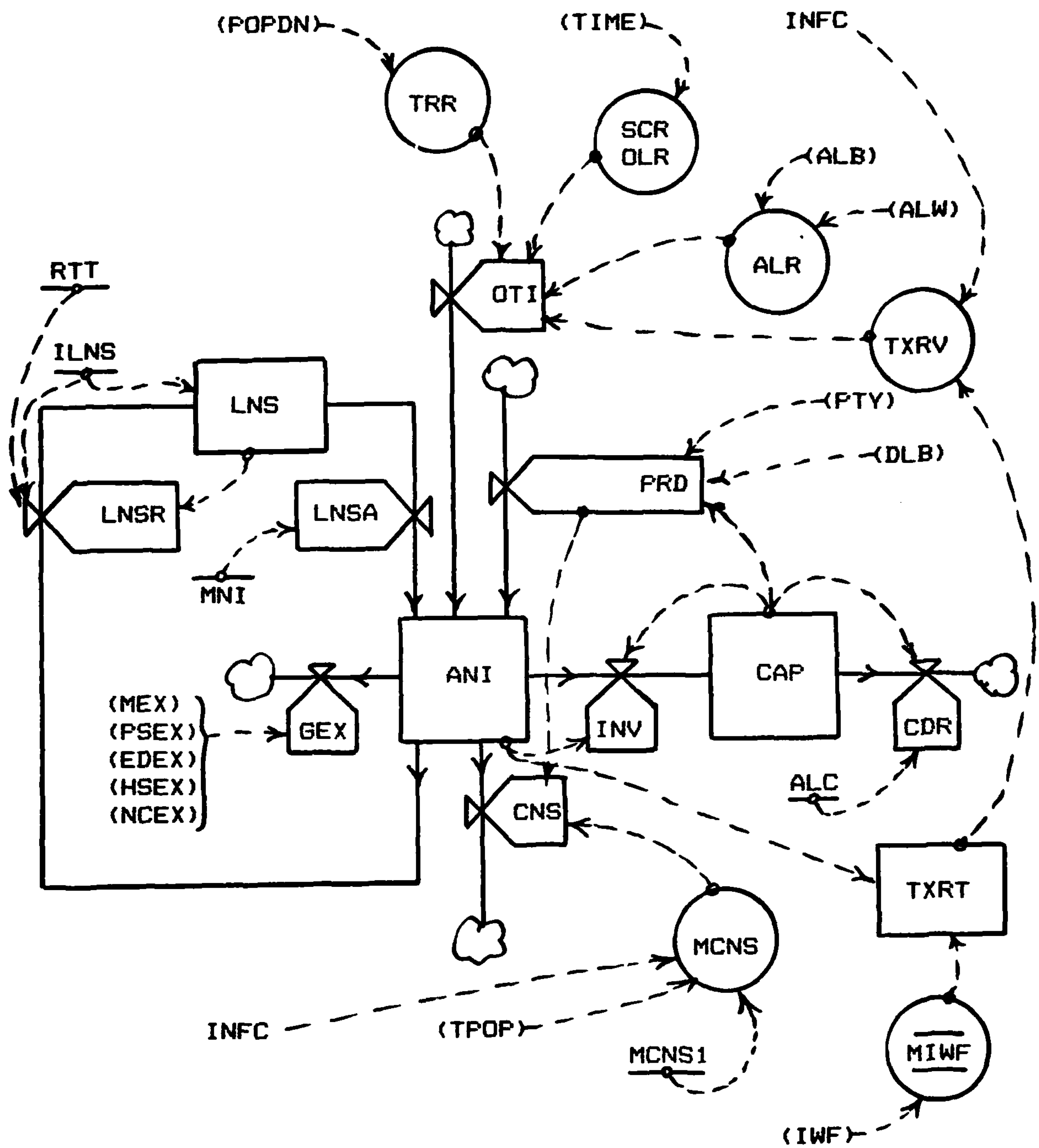
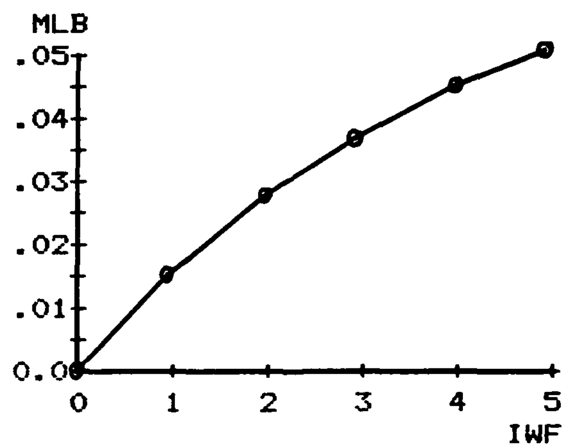


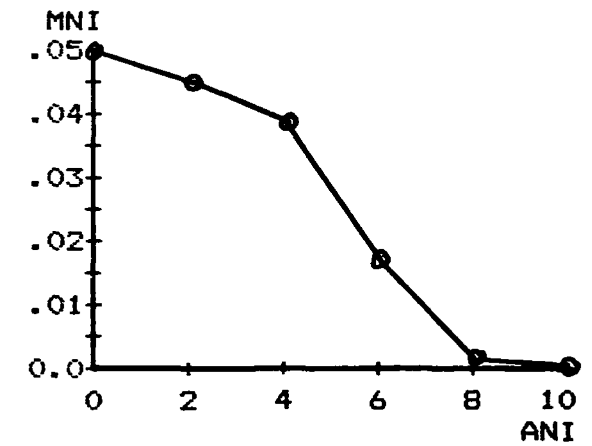
Figure 3.14 Flow Diagram of the Capital Sector

As the level of idle work force increased, the government decreases the tax ratio to encourage more investments which lead to more hiring of labor. This relationship is represented in figure 3.15 as a table function of idle workforce multiplier. As the accumulated national income decrease the government increases the tax ratio to increase the tax revenue. A multiplier from the accumulated income on tax ratio is represented as a table function (figure 3.16). The relation between population density and tourism revenue is represented in figure 3.17.



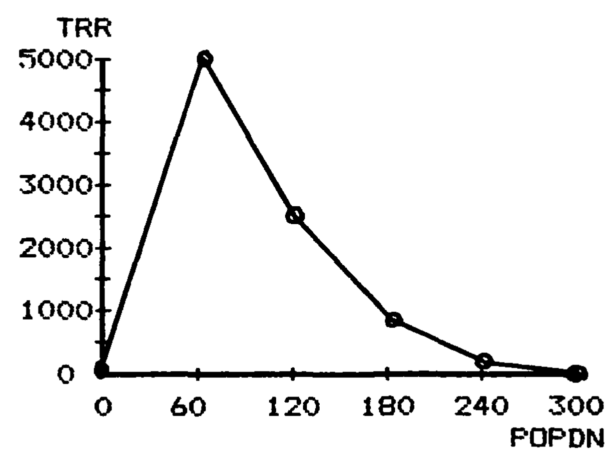
Labor Multiplier (MLB)	0.0	.015	.027	.037	.045	.05
Idle Workforce (IWF)	0	1	2	3	4	5

Figure 3.15 Table Function of Labor Multiplier



Multiplier from Accumulated National Income	.05	.045	.037	.017	.001	0.0
Accumulated National Income	0	2	4	6	8	10

Figure 3.16 Table Function of Accumulated Income Multiplier



Population Density (POPDN)	0	60	120	180	240	300
Tourism Revenue (TRR)	50	5000	2500	800	80	50

Figure 3.17 Table Function of Tourism Revenue

The DYNAMO formulation and data dictionary of this sector is listed bellow.

```
L     ANI.K=ANI.J+(DT)(PRD.JK+OTI.JK+
X       LNSA.JK-INV.JK-CNS.JK-GEX.JK           CS1
N     ANI=10                                   CS2
R     PRD.KL=PTY.K*CAP.K*EXP(0.65*
X       LOGN(DLB.K/CAP.K))                     CS3
R     OTI.KL=TRR.K+SCR.K+OLR.K+ALR.K+TXRV.K    CS4
A     TRR.K=TABLE(TTRR,POPDN,0,300,60)         CS5
T     TTRR=50/5000/2500/800/80/50
A     POPDN.K=TPOP.K/HABA.K                    CS6
L     SCR.K=SCR.J*(1+0.1*DT/TIME.K)            CS7
L     OLR.K=PLR.J*(1+0.1*DT/TIME.K)            CS8
N     SCR=500                                  CS9
N     OLR=500                                  CS10
A     ALR.K=ALB.K*ALW.K/2                      CS11
A     TXRV.K=TXRT.K*CAP.K*INFC                 CS12
R     LNSA.KL=MAX(MNI-ANI.K,0.0)               CS13
R     INV.KL=ANI.K*INVF.K                      CS14
A     INVF.K=TABLE(TINVF,TXRT,0,1,.2)          CS15
T     TINVF=0.3/.25/.20/.10/.05/0.0
L     TXRT.K=TXRT.J+(DT)(MNI.K-MLB.K)(TXRT.J)  CS16
A     MLB.K=TABLE(TMIWF,IWF.K,0,5,1)           CS17
T     TMLB=0.0/.015/.027/.037/.045/.05
A     MNI.K=TABLE(TMNI,NI.K,0,10E4,2E4)        CS18
T     TMNI=.05/.045/.037/.017/.001/0.0
R     CNS.KL=MIN(PRD.KL,TPOP.K*MCNS1*INFC)     CS19
R     GEX.KL=MEX.K+PSEX.K+EDEX.K+
X       HSEX.K+NCEX.K                          CS20
L     CAP.K=CAP.J+(DT)(INV.JK-CDR.JK)          CS21
N     CAP=7.5E3                                CS22
R     CDR.KL=CAP.K/ALC                         CS23
C     ALC=20                                   CS24
```

```
ALC  = Average Life of Capital              (years)
ALR  = Revenue Rate of Labor Working Abroad
                                      ($ per year)
ANI  = Accumulated National Income             ($)
CAP  = Capital Stock                           ($)
CDR  = Rate of Depreciation of Capital
                                      ($ per year)
CNS  = Rate of Consumption            ($ per year)
GEX  = Expenditure Rate of Government
                                      ($ per year)
INV  = Rate of Investment             ($ per year)
INVF = Investment Fraction         (dimensionless)
LNSA = Access Rate of Loans           ($ per year)
```

MCNS = Minimum Consumption per Capita ($ per person per year)
MLB = Multiplier from Idle Labor on Tax Ratio (dimensionless)
MNI = Multiplier from Accumulated National Income on Tax Ratio (dimensionless)
OLR = Revenue Rate of Oil ($ per year)
OTI = Rate of Other Sources of Income ($ per year)
POPDN= Population Density (person per square mile)
PRD = Rate of Production ($ per year)
PTY = Productivity (dimensionless)
SCR = Revenue Rate of Sues Canal ($ per year)
TRR = Revenue Rate of Tourist ($ per year)
TXRT = Ratio of Taxes (dimensionless)
TXRV = Revenue Rate of Taxes ($ per year)

Housing Sector

Shortage of housing is one of the main problems in the country [29]. To solve this problem, the policy of the government is to develop new areas that are suitable for building houses, to build houses, and to distribute them among the people. The housing units are built and distributed by different governmental agencies which have no common data-base. Without complete and relevant information for every agency about the whole market, the distribution of houses may be repeated. The repetition of distribution creates two problems, the first is that the houses received by the real housing demand is less than the houses built by the government. The second is that a fraction of land occupied will be consumed without real effect on the demand. Decreasing the fraction of land occupied causes a decrease

in the construction rate of both government and private houses which hinders the solution of the problem. Figure 3.18 depicts the main causal-loops in this sector.

Figure 3.19 is the corresponding flow diagram of the housing sector. The flow of houses is through two levels, the houses built by the government (GHSB) and the houses built by the private sector (PHSB). The housing demand (HHDM) is the difference between the number of families and the summation of both houses built by the private sector (PHSB) and houses received by real demand (GHSR). The fraction of land occupied by houses (FLOC) is the ratio between the land occupied by houses and the available land for building houses (HABA). The land occupied by houses is equal to the total number of houses built divided by the average area of each house. The rate of access to the level of houses built by the government (GCNST) depends on the government plan (GCNSTP), the housing demand (HHDM), and the fraction of land occupied (FLOC). The rate of departure from this level of houses built by government (GDMOL) depends on the level and the average life of a house (HSAL). The rate of access to the level of houses built by the private sector (PCNST) depends on the housing demand (HHDM) and the fraction of land occupied (FLOC). The rate of departure from the level of houses built by the private sector (PDMOL) depends on the level and the average life of a house (HSAL).

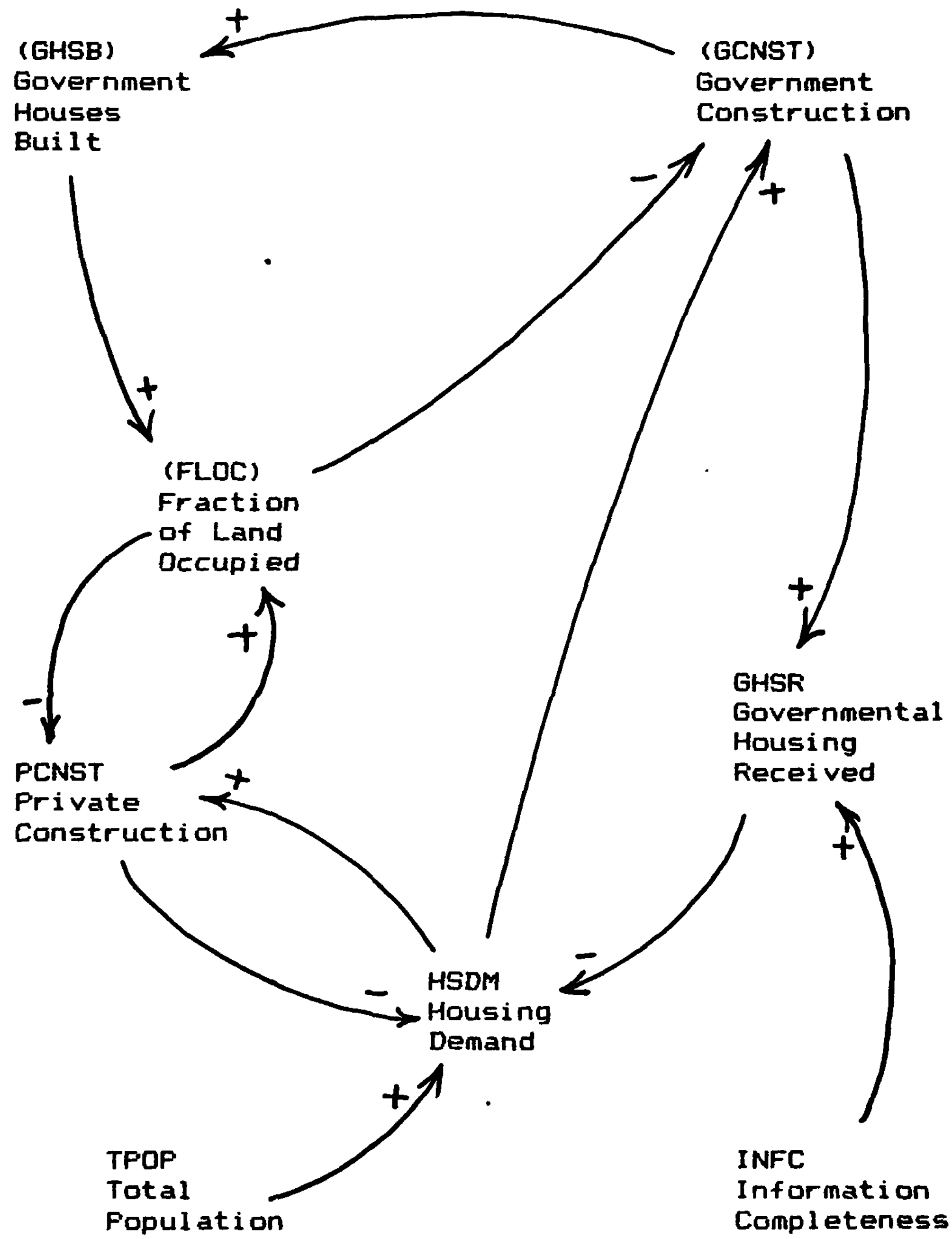


Figure 3.18 Causal-Loop Diagram of the Housing Sector

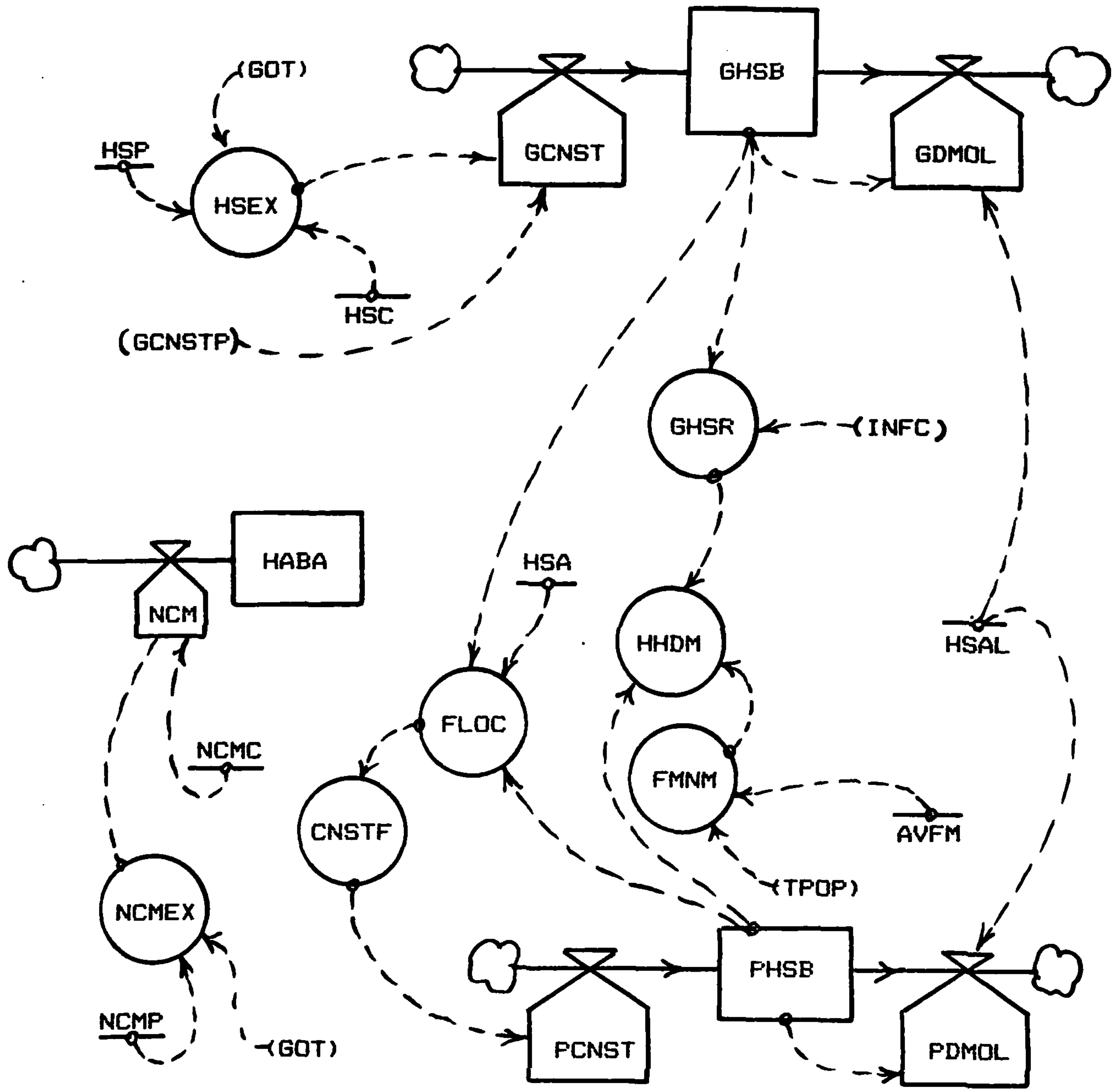
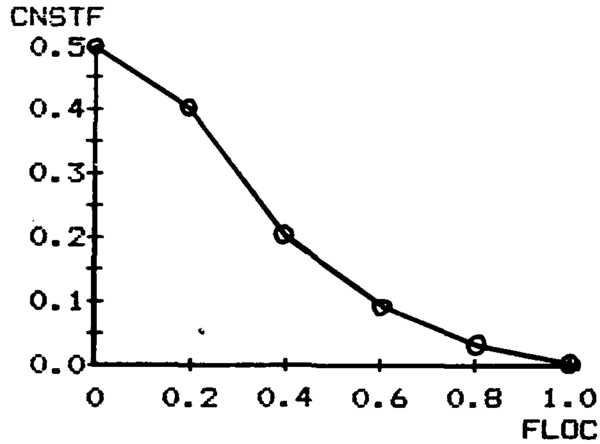


Figure 3.19 Flow Diagram of the Housing Sector



Fraction of Land Occupied (FLOC)	0.0	0.2	0.4	0.6	0.8	1.0
Construction Factor (CNSTF)	0.5	0.4	0.2	0.1	0.03	0.0

Figure 3.20 Table Function of Construction Factor.

The relation between the fraction of land occupied and construction of houses is represented by the table function included in figure 3.20.

The DYNAMO equations and data dictionary of this sector are listed bellow.

```
L     GHSB.K=GHSB.J+(DT)(GCNST.JK-GDMOL.JK)      HS1
N     GHSB=0.8                                   HS2
L     PHSB.K=PHSB.J+(DT)(PCNST.JK-PDMOL.JK)      HS3
N     PHSB=7.2                                   HS4
R     GDMOL.KL=GHSB.K/HSAL                       HS5
R     PDMOL.KL=PHSB.K/HSAL                       HS6
R     GCNST.KL=MIN(HSEX.K/HSC,HSDM.K)            HS7
C     HSC=5E-3                                   HS8
A     HSEX.K=GOT.K*USP                           HS9
C     HSP=0.15                                   HS10
A     HSDM.K=MAX(FMNM.K-GHSR.K-PHSB.K,0.0)       HS11
A     GHSR.K=GHSB.K*INFC                         HS12
A     FMNM.K=TPOP.K/AVFM                         HS13
C     AVFM=5                                     HS14
R     PCNST.KL=HSDM.K*CNSTF.K                    HS15
A     CNSTF.K=TABLE(TCNSTF,FLOC.K,
X       0.0,1.0,0.2)                             HS16
T     TCNSTF=0.5/0.4/0.2/0.1/0.03/0.0
```

```
A     FLOC.K=(GHSB.K+PHSB.K)*HSA/HABA.K/5       HS17
C     HSA=5E-4                                  HS18
L     HABA.K=HABA.J+(DT)(NCM.JK)                HS19
N     HABA=2.8E5                                HS20
R     NCM.KL=NCMEX.K/NCMC                       HS21
A     NCMEX.K=GOT.K*NCMP                        HS22
C     NCMP=0.15                                 HS23
C     NCMC=3E-3                                 HS24
C     HSAL=60                                   HS25
```

AVFM = Average Number of persons of a Family (person per family)
CNSTF = Construction Factor (dimensionless)
FLOC = Fraction of Land Occupied (dimensionless)
FMNM = Number of Families (families)
GCNST = Construction Rate of Government (house per year)
GDMOL = Demolition Rate of Houses Built by Government (house per year)
GHSB = Houses Built by Government (houses)
HABA = Land Available for Building Houses (square miles)
HSA = Average area of a house (square miles)
HSAL = Average Life of a House (years)
HSC = Average Cost of a House ($ per house)
HSDM = Demand on Housing (houses)
HSEX = Government Expenditure on Housing ($ per year)
HSP = Priority of Housing (dimensionless)
NCM = Rate of Development of New Communities (square miles per year)
NCMC = Cost of New Communities ($ per square mile)
NCMEX = Expenditures on New Communities ($ per year)
NCMP = Priority of New Communities (dimensionless)
PCNST = Construction Rate of Private Sector (house per year)
PDMOL = Demolition Rate of Houses Built by Private Sector (house per year)
PHSB = Houses Built by Private Sector (house per year)

The five sectors are integrated and tested as a single unit. The next chapter presents the testing and verification phase of the model development.

Summary

Chapter three has presented the conceptualization of the national development process, the sectorization of the development system, and the formulation of each sector. Five sectors have been discussed which are demographic, military, labor, capital, and housing. Chapter four presents the model testing which was performed to establish the validity of the model for the purpose of the study.

IV. MODEL TESTING AND VALIDATION

Introduction

Confidence in a System Dynamics model can be increased by a wide variety of tests. According to Forrester and Senge, testing is:

> "The comparison of a model to empirical reality for the purpose of corroborating or refuting the model. It is important to realize that the word "empirical" means "derived from or guided by experience or experiment" ... Hence empirical information for testing a model includes information in many forms other than numerical statistics. In system dynamics models, model structure can be compared directly to descriptive knowledge of real-system structure; and model behavior may be compared to observed real-system behavior." [10:210].

In System Dynamics, testing serves three purposes: (1) to reveal errors in model structure (and thereby improve the structure), (2) to better understand the causes of model behavior and real behavior, and (3) to provide information useful for validation. Validation is defined as:

> "establishing confidence in the soundness and usefulness of a model. Validation begins as the model builder accumulates confidence that a model behaves plausibly and generates problem symptoms or modes of behavior seen in the real system. Validation then extends to include persons not directly involved in constructing the model. Thus, validation includes the communication process in which the model builder (or someone else presenting a model) must communicate the bases for confidence in the model to a target audience. Unless the modeler's confidence in a model can be transferred,

> the potential of a model to enhance understanding and lead to a more effective policies will not be realized." [10:210].

There is no single test which serves to "validate" a System Dynamics model. Rather, confidence in a System Dynamics model accumulates gradually as the model passes more tests and as new points of correspondence between the model and empirical reality are identified. By building and testing the model in stages (as was done in this study), the understanding and confidence continually grew with each stage of development. This chapter extends the validation process to its later stages by reporting the tests which have led to some level of confidence that the model is useful for the purpose of study.

Forrester and Senge [10:227] describe an array of tests (table 4.1) which can be applied to System Dynamics models for building confidence. All of the "core tests" identified in table 4.1 were accomplished on this model. Each test is briefly defined, the usefulness of the test to the purpose of the study is discussed, and results are presented.

Tests of Model Structure

Tests of model structure consider the structure and parameters of the model without considering the relationship between structure and behavior. Five tests are included in this category. All of them are considered core tests, because they are intrinsically part of constructing a

Tests of Model Structure:

*1. Structural Verification.
*2. Parameter Verification.
*3. Extreme Conditions.
*4. Boundary Adequacy.
*5. Dimensional Consistency.

Tests of Model Behavior:

*1. Behavior Reproduction.
2. Behavior Prediction.
*3. Behavior Anomaly.
4. Family Member.
5. Surprise Behavior.
6. Extreme Policy.
7. Boundary Adequacy.
*8. Behavior Sensitivity.

Tests of Policy Implications:

1. System Improvement.
*2. Changed Behavior Production.
3. Boundary Adequacy.
*4. Policy Sensitivity.

Table 4.1. Confidence Building Tests

(* = Core Tests)

System Dynamics model. The next five items describe the tests of model structure.

Structure-Verification Test. The structure-verification test consists of comparing the model structure with the structure of the real system that the model represents [10:212]. It was first conducted on the basis of the model

builder's personal knowledge and was then extended to include criticism by others with direct experience from the real system. Two rounds of interviews with researchers from the field were conducted. The first round of interviews resulted in some changes in causal relationships included in the model, while generally supporting the basic approach. The cause of health level is considered not only the health care efforts but also the public services including broadcasting, communication, and social activities. The average productive life is dependent not only on death rate but also on the health level. After making these changes, the model structure accurately reflects existing knowledge and understanding of the system.

Parameter-Verification Test. As the structure of a model is compared to available knowledge, model parameters (constants) can be verified against observations from real life. The parameter-verification test involves comparing model parameters to knowledge of the real system to determine if parameters correspond conceptually and numerically to real life. Conceptual correspondence means that parameters match elements of system structure. Numerical verification involves determining if the value given the parameter falls within a plausible range of values for the actual correction time [12:125]. This test was accomplished through both literature research and interviews. All the parameters in the model have

corresponding elements in the real system. The remaining part then is the numerical verification. For parameters whose real world counterparts can be readily measured, actual values were obtained from literature research or interviews. The values of other less readily measurable parameters were estimated. In the case of table functions, which are in fact sets of several parameters, Graham [12:128-130] suggests that one estimate the value and slope of the function at the extremes and the normal value and then connect these known values and slopes with a smooth curve. This method was followed for several table functions in the model, including the tables for birth rate fraction (DS5), death rate fraction (DS25), and housing-construction factor (HS17). Alternative plausible shapes of these table functions were tested, and the model behavior was found to be insensitive to the exact values in the table functions. Certain of the parameters, most notably the multipliers from idle workforce and accumulated national income on tax ratio, were estimated using another of Graham's techniques [12:136-138]. The parameters were tested over a broad range of possible values, with the combination of values for which the model behavior most closely resembled real system behavior selected for use in the model.

<u>Extreme-Condition Test.</u> The extreme-condition test investigates the consequences of extreme conditions of the system and if the structure of the model permits extreme

conditions of levels (state variables) in the system represented. The extreme-conditions test is effective for two reasons. First, it is a powerful test for discovering flaws in model structure. Many proposed formulations look plausible until considered under extreme conditions. Considering extreme conditions can also reveal omitted variables. The second reason for utilizing the extreme-condition test is to enhance usefulness of a model for analyzing policies that may force a system to operate outside historical regions of behavior. A model which only behaves plausibly under "normal" conditions can only be used to analyzed policies which do not caused the system to operate outside of those conditions. In the extreme--condition test, one must examine each rate equation (policy) in the model, trace is back through auxiliary equations to the level (state variables) on which the rate depends, and consider the implication of imaginary maximum and minimum (minus infinity, zero, plus infinity) values of each state variable and combinations of state variables to determine the plausibility of the resulting rate equations.

Boundary-Adequacy (structure) Test. The boundary-adequacy test considers structural relationships necessary to satisfy a model's purpose. The test asks whether or not model aggregation is appropriate and if a model includes revelent structure. As a test of model structure, the boundary adequacy test involves developing a convincing

hypothesis relating proposed model structure to a particular issue addressed by a model. If one wishes, model boundaries can be extended indefinitely as one incorporates into a model further aspects of system structure which even if accurate, are not necessary for the particular purpose. The boundary of this study is affected directly by the stated governmental policy for national development.

Dimensional-Consistency Test. The dimensional-consistency test [10:215-216] entails dimensional analysis of the model's rate equations. This test was performed on each equation of the model during model formulation.

Tests of Model Behavior

Tests of model structure, which are described in the preceding section, do not consider the relationship between structure and behavior of the model. To evaluate the adequacy of the model structure, the behavior generated by the model has had to be analyzed and tested. Three tests of model behavior were conducted. The following items briefly describe each of these tests.

Behavior-Reproduction Tests. The group of behavior-reproduction tests examines how well model generated behavior matches observed behavior of the real system. Behavior-reproduction tests include: symptom generation, frequency generation, relative phasing, multiple mode, and behavior characteristic tests [10:217-219].

The symptom-generation test examines whether or not the model recreates the problem symptoms which motivated construction of the model.

The frequency-generation and relative-phasing tests focus on periodicities of fluctuation and phase relationships between variables.

The multiple mode test considers whether or not a model is able to generate more than one mode of observed behavior.

The behavior-characteristic test is included as a miscellaneous category for other behavior-reproduction test. Aspects of behavior such as a peculiar shape of a fluctuating time series (e.g., sharp peaks and long troughs) may be the focus of a behavior-characteristic test.

Behavior-Anomaly Test. In constructing and analyzing a System Dynamics model, one expects it to behave like the real system under study. If the model has anomalous behavior which sharply conflicts with behavior of the real system, the elements of model structure responsible for this behavior have to be investigated. In this study, the test was used mainly during model development. Numerous behavior anomalies were observed which led to reformulation of model equations in order to eliminate the anomalies.

Behavior-Sensitivity Test. This test focuses on sensitivity of model behavior to changes in parameter values. The behavior-sensitivity test ascertains whether or not plausible shifts in model parameters can cause a model

to fail a behavioral test previously passed. To the extent that such alternative parameter values are not found. confidence in the model is enhanced. In this study, the test was typically conducted by experimenting with different parameter values and analyzing their impact on behavior. The model was found sensitive to the parameters of Cobb-Doglass function in the capital sector. More study on those parameters is required.

Tests of Policy Implications

Tests can be conducted to build confidence in a model's implications for policy. Although all tests of a System Dynamics model aim at usefulness of a model as a policy-analysis tool, tests of policy implications differ from other tests in their explicit focus on comparing policy changes in a model and in the corresponding reality. Policy implication tests attempt to verify that response of a real system to a policy change would correspond to the response predicted by a model. The test also examines how robust are policy implications when changes are made in boundaries or parameters. Since the major purpose of this research is to study the effects of improving the quality of information on the adopted policy of national development, the testing in this area was not extensive. The following discussion will therefore be limited to a description of the tests, and how they might be applied.

Changed-Behavior-Prediction Test. The changed-behavior-prediction test asks if a model correctly predicts how behavior of the system will change if a governing policy is changed. In this study the test was performed by examining the response of the model to policies which have been persuaded in the real system to see if the model responds to a policy change as the real system responded.

Policy-Sensitivity Test. Parameter sensitivity testing can, in addition to revealing the degree of robustness of model behavior, indicate the degree to which policy recommendations might be influenced by uncertainty in parameter values. Such testing can help to show the risk involved in adopting a model for policy making. If the same policies would be recommended regardless of parameters values within a plausible range, risk in using the model will be less than if two plausible sets of parameters lead to opposite policy recommendations.

Summary

This chapter has described the tests which were performed in order to build confidence that the model is useful for the purpose of the study. Using this model, the next chapter presents the experimentation phase of the research.

V. Experimentation Results, Recommendations, and Conclusion

Introduction

The preceding chapter presented the tests of model structure and behavior. This chapter extends the operation of the model into the realm of experimentation. As stated in the first chapter, the main objective of developing such a model is to help the decision maker assess the value of information and estimate the benefits of developing the national information system. The value of information, on this level, can only be assessed from the changes in the national development process which accompany its use [41:57]. So, the experiments, in this chapter, are directed at studying the effects of changes in information quality attributes on the level of achievement of the national development objectives.

> "Model-based policy analysis involve the use of the model to help investigate why particular policies have the effects they do and to identify policies that can be implemented to improve the problematic behavior of the real system. The goal is an understanding of what policies work and why." [32:321].

The results of the experiments, as with any analytical tool, provide information which a decision maker can use together with intuition, judgment, and experience to make policy decisions. Discussed in this chapter are the

experiment conceptualization, effects on the four objectives of the development process, recommendations, and the conclusion.

Experimental Conceptualization

In the model construction, decisions are modeled as a combination of information flows describing the status and objectives of the system. Information entering a decision is assumed to be available with certain levels of accuracy and timeliness. The level of accuracy is represented by the parameters INFC, PRCH, and USMN which control NOISE and NORMRN functions. The level of timeliness is represented by SMOOTH and DLINF3 functions. Those levels are changed through two experiments. The first experiment considers the development process with the present level of information quality. The second one considers the development process with the objective level of information quality. The effects of these changes on the objectives of the national development process are developed using the stated measures of each objective.

As mentioned in chapter three, the development plan has four objectives to achieve. The first, increasing investment rate to achieve full employment. The measures of this objective are the idle workforce (IWF), domestic labor (DLB), and labor working abroad (ALB).

The second objective is to achieve a balance between

production and consumption by increasing the output of the production sector. The measures of this objective are the consumption per capita (CNS1) and the production rate (PRD).

The third objective of the development plan is to keep the armed forces on the same level of manpower while acquiring more sophisticated weapons. Since the proposed information system is considered that have no effects on the process of weapon systems acquisition, the measures of this objective are the number of draftees under training (DAT) relative to the productive draftees (DUS).

The fourth objective is to improve the standard of living of people by increasing the family consumption rate, increasing the public consumption (public services), and satisfying the demand on housing. The measures of this objectives are the consumption rate per capita (CNS1), the public expenditure per capita (PSEX1), and housing demand (HSDM).

For each one of those objectives, the results of experiments are described and discussed in the following sections.

Effects on the First Objective of Development

The first objective of development is concerned with the level of employment. The model provides information about the numbers of idle workforce, domestic labor, and labor working abroad. Table 5.1 includes a summary of these

information and comparisons between the effects of the two levels of information quality.

Time (years)	Basic level of Quality			Revised Level of Quality		
	Labor in Millions:			Labor in Millions:		
	Idle (IWF)	Domestic (DLB)	Abroad (ALB)	Idle (IWF)	Domestic (DLB)	Abroad (ALB)
0	2.6000	11.000	1.0000	2.6000	11.000	1.0000
5	0.4381	14.689	0.9739	0.6122	14.514	0.9739
10	0.4778	16.024	0.9486	0.6077	15.893	0.9486
15	0.5227	17.160	0.9238	0.5938	17.103	0.9248
20	2.0391	16.580	0.8997	0.5634	18.158	0.9063
25	3.4991	15.773	0.8763	0.5246	19.004	0.8924
30	2.2845	17.397	0.8535	0.4921	19.655	0.8822
35	0.3432	19.575	0.8312	0.4713	20.182	0.8757
40	0.3043	19.742	0.8095	0.4590	20.632	0.8719
45	0.2867	19.821	0.7884	0.4540	21.047	0.8705
50	0.2740	19.877	0.7688	0.4532	21.422	0.8696
55	0.2644	19.951	0.7518	0.4557	21.770	0.8686
60	0.2562	20.054	0.7374	0.4597	22.104	0.8676

Table 5.1 Effects on the First Objective of Development

On the basic level of information quality, the table shows a steady increase in labor working inside and a steady decrease in labor working outside the country. This may be referred to the governmental policy to increase the production and encourage investments inside the country. Although the table shows a tendency to decrease idle workforce, it is increased significantly in the period between 15 and 30 years of the time reference. This may be referred to the delay in information required to adjust the mechanism of development.

On the revised level of information quality, the table shows a substantial increase in the numbers of working labor relative to the corresponding numbers of labor on the basic level of information quality. This is due to the improvement of the development system as a whole which happened after improving the quality of information. However, the idle workforce also increased which may be referred to the increase in productive life of an employee due to the decrease in death rate and the increase in health level of the workforce. The table also shows no contingency increase in idle workforce in the period years number 15 and 30 of the time reference.

Effects on the Second Objective of Development

The second objective of development is concerned with the rates of consumption per capita and production. Table 5.2 illustrate the rate of consumption per capita per year and the rate of production per year on both the two levels of information quality. Throughout the time reference of the model, the table shows a substantial increase in both consumption per capita and production on the revised level of information quality. There are two factors that affect the increase in consumption per capita which are the increase in production and the improvement in allocation of subsidization.

Time (years)	Basic Level of Quality		Revised Level of Quality	
	Consumption ($/capita /year)	Production ($ billions /year)	Consumption ($/capita /year)	Production ($ billions /year)
0	500.00	11.937	500.0	11.937
5	500.00	16.606	500.0	17.966
10	500.00	21.626	500.0	22.847
15	500.00	21.019	540.9	25.843
20	500.00	20.672	608.2	28.851
25	500.00	18.120	675.3	31.809
30	500.00	20.956	748.8	35.176
35	500.00	22.122	833.4	39.184
40	500.00	23.071	938.4	44.284
45	500.00	24.029	1070.4	50.812
50	546.63	27.372	1237.3	59.139
55	559.04	27.890	1449.6	69.804
60	632.80	31.507	1721.4	83.555

Table 5.2 Effects on the Second Objective of Development

Effects on the Third Objective of Development

The model considers two measures of the third objective of development which are the draftees under training relative to the productive draftees. For the same level of military forces, a lower number of draftees under training implies a lower cost and higher efficiency. Table 5.3 shows a decrease in the number of draftees under training throughout the time reference of the model. This is attributed to the improvement of information which is exchanged between the education, civilian, and military sectors for adjusting the allocation of people on the

appropriate activities.

Time (years)	Basic Level of Quality		Revised Level of Quality	
	Draftees in Millions: Under Training (DAT)	Draftees in Millions: Productive (DUS)	Draftees in Millions: Under Training (DAT)	Draftees in Millions: Productive (DUS)
0	.26000	.54000	.26000	.54000
5	.25527	.57087	.25487	.57085
10	.25187	.57969	.24966	.57981
15	.25009	.58218	.24593	.58239
20	.24946	.58301	.24030	.58326
25	.24882	.58296	.23966	.58323
30	.24933	.58288	.23016	.58316
35	.24906	.58278	.23989	.58305
40	.24924	.58283	.24008	.58310
45	.24918	.58295	.24001	.58322
50	.24921	.58286	.24004	.58313
55	.24895	.58291	.23978	.58319
60	.24897	.58282	.23980	.58310

Table 5.3 Effects on the Third Objective of Development

Effects on the Fourth Objective of Development

The fourth objective of development is concerned with the people's standard of living. The defined measures for this objective are the rate of consumption per capita, the public services expenditures, and housing unsatisfied demand. Table 5.4 shows the degree of change in each one of these measures due to the improvement in the quality of information.

Time (years)	Basic Level of Quality			Revised Level of Quality		
	CNS1	PSEX1	HSDM	CNS1	PSEX1	HSDM*
0	500.00	21.74	1.280	500.0	21.74	1.280
5	500.00	27.02	0.135	500.0	27.02	0.126
10	500.00	32.06	0.125	500.0	32.06	0.117
15	500.00	36.34	0.109	540.9	36.36	0.103
20	500.00	39.37	0.093	608.2	39.47	0.092
25	500.00	41.99	0.096	675.3	42.28	0.097
30	500.00	44.67	0.097	748.8	45.25	0.102
35	500.00	47.46	0.098	833.4	48.43	0.106
40	500.00	50.36	0.099	938.4	51.84	0.109
45	500.00	53.40	0.099	1070.4	55.51	0.112
50	546.63	56.63	0.100	1237.3	59.40	0.114
55	559.04	60.10	0.102	1449.6	63.54	0.116
60	632.80	63.83	0.104	1721.4	67.92	0.117

Figure 5.4 Effects on the Fourth Objective of Development

*CNS1 = Rate of Consumption per Capita ($/capita/year)
HSDM = Demand on Housing (millions of houses)
PSEX1= Public Services Expenditures per Capita ($/capita/year)

Recommendations

The model developed in this study provides a broad-based structure of the development process in Egypt. The model is directed at development of a comprehensive governmental information system. The model is used to investigate the impact of changes in information quality on the development process, to assess the value of information, and to estimate the benefits of a national information system and discuss its requirements. In a model on such a level of complexity,

many relationships and interactions have to be estimated to be included in the system model.

> "Much of the behavior of systems rests on relationships and interactions that are believed, and probably correctly so, to be important but that for a long time will evade quantitative measure. Unless we take our best estimates of these relationships and include them in a system model, we are in effect saying that they make no difference and can be omitted. It is far more serious to omit a relationship that is believed to be important than to include it at a low level of accuracy that fits within the plausible range of uncertainty. ... If one believes a relationship to be important, he acts accordingly and makes the best use he can of the information available. He is willing to let his reputation rest on his keenness of perception and interpretation." [8:114].

However, there are several areas in which further research would be useful. These areas are identified in the following four paragraphs.

Econometrics and Aggregation Theory. Econometrics is concerned with the empirical determination of economic laws which identify behavioral or technical relations of an economy. A behavioral relation describes how consumers behave, on the average, with regard their purchases of goods, given the relative price level of these goods as well as real income per capita. A technical relation describes how any input combination (factors of production) leads to a particular (maximum) output (production). These relationships interact on both macro and micro levels. The analysis of the relationships between micro- and macrorelations is known as aggregation theory. In the capital sector of this model, the estimation of production

function (CS3) and effects of tax ratio on investment rate (CS15) are built upon general data and interviews. They were tested and adjusted to provide model behavior consistent with those data and interviews. An econometric model and some aggregation analysis would improve the understanding and enhance formulation of the System Dynamics model.

Job Specifications. The interactions of workforce between education, civilian, and military sectors are affected by an integrated information system. However, a concrete job specification schedule would be necessary to feed this system.

Patterns of Development. The only pattern of development considered in this study is the official one. Because the time reference of the study covers 60 years, it may be helpful to discuss and consider another patterns of development which may be considered in certain phases of growth.

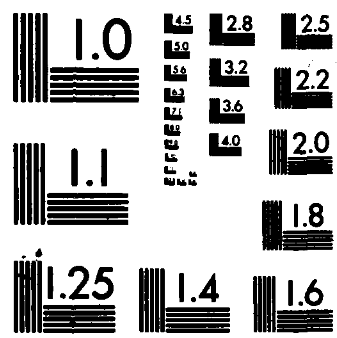
Including Costs of System Development. The total costs of developing the proposed information system and the way of payment are main factors required for the decision maker. Including those costs in the model is a necessary subsequent phase of the study. It is expected that the rate of achievement of the development objectives will be affected for certain period according to the amount and time of payment for the system.

Conclusion

In conclusion, the objective of this study was accomplished. The model developed in the study provides a broad-based structure of the development process in Egypt. The model is directed at development of a comprehensive governmental information system. As a decision making tool, the model can provide additional information for a decision maker to use in conjunction with intuition, judgment, and experience to evaluate proposed information systems. The model is also useful as an aid in investigating the impact of changes in information quality on the development process, assessing the value of information, and estimating the benefits of a national information system and discussing its requirements. Recommendations have been introduced for further research which will enhance the model's usefulness for both information evaluation and other policies of development.

AD-A141 051 A SYSTEM DYNAMICS APPROACH TO MEASURING THE VALUE OF INFORMATION(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF ENGINEERING M M KABIL DEC 83 2/2

UNCLASSIFIED AFIT/GOR/OS/83D-6 F/G 5/1 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

APPENDIX A

VARIABLE LISTING

Variable Name	Variable Description	Units of Measure
AAL	Access Rate of Abroad Labor	person/year
AALF	Access Rate Fraction of Abroad Labor	dimensionless
AAR	Access Rate of Adult Population	person/year
ABF	Fraction of Retirement of Abroad Labor	dimensionless
ADAT	Rate of Access to Draftees Under Training	person/year
ADPOP	Adult Population	person
ADUS	Rate of Access to Productive Draftees	person/year
AERT	Adjusted Education Ratio	dimensionless
AL	Access of Domestic Labor	person/year
ALB	Labor Working Abroad	person
ALBT	Access Rate of Labor Needs Training	person/year
ALC	Average Life of Capital	years
ALR	Revenue Rate of Labor Working Abroad	$/year
ALW	Wages of Abroad Labor	$/person/year
ANI	Accumulated National Income	$
APL	Average Productive Life	years
ARF	Fraction of Draftees Who Do Not Need Training	dimensionless
AVF	Rate of Access of Professionals	person/year
AVFM	Average Number of persons of a Family	person/family
BR	Birth Rate	person/year
BRF	Birth Rate Fraction	fraction/year
CAP	Capital Stock	$
CDR	Rate of Depreciation of Capital	$/year
CNS	Rate of Consumption	$/year
CNS1	Rate of Consumption per Capita	$/person/year
CNSTF	Construction Factor	dimensionless
DAT	Draftees Under Training	person
DDUS	Rate of Departure of Draftees	person/year
DLB	Domestic Labor	person
DLW	Wages of Domestic Labor	$/person/year
DP	Draft Service Period	year
DR	Death Rate	person/year
DRF	Death Rate Fraction	fraction/year
DUS	Productive Draftees	person
DVF	Rate of Retirement of Professionals	person/year
EDC	Education Cost	$/pupil/year
EDEX	Education Expenditure	$/year
EDEX1	Education Expenditure per pupil	$/pupil/year
EDP	priority of Education	dimensionless
EDRT	Education Ratio	dimensionless

FLOC	Fraction of Land Occupied	dimensionless
FMNM	Number of Families	families
GCNST	Construction Rate of Government	house/year
GDMOL	Demolition Rate of Houses Built by Government	house/year
GEX	Expenditure Rate of Government	$/year
GHSB	Houses Built by Government	houses
GOT	Government Social Expenditure	$/year
HABA	Land Available for Building Houses	square miles
HLF	Health Factor	dimensionless
HSA	Average area of a house	square miles
HSAL	Average Life of a House	years
HSC	Average Cost of a House	$/house
HSDM	Demand on Housing	houses
HSEX	Government Expenditure on Housing	$/year
INFC	Information Completeness	dimensionless
INV	Rate of Investment	$/year
INVF	Investment Fraction	dimensionless
IWF	Idle Work Force	person
LBT	Rate of Training of Labor	person/year
LNSA	Access Rate of Loans	$/year
LWRTI	Ratio of Differences of Wages	dimensionless
MCNS	Minimum Consumption per Capita	$/person/year
MLB	Multiplier from Idle Labor on Tax Ratio	dimensionless
MNI	Multiplier from Accumulated National Income on Tax Ratio	dimensionless
NCM	Rate of Development of New Communities	square miles/ year
NCMEX	Expenditures on New Communities	$/year
OLR	Revenue Rate of Oil	$/year
OTI	Rate of Other Sources of Income	$/year
PCNST	Construction Rate of Private Sector	house/year
PDMOL	Demolition Rate of Houses Built by Private Sector	house/year
PHSB	Houses Built by Private Sector	house/year
POPDN	Population Density	person/square mile
PRCH	Rate of Technological Change	dimensionless
PRD	Rate of Production	$/year
PSEX	Public Service Expenditure	$/year
PSEX1	Public Service per Capita	$/person/year
PSP	Priority of Public Services	dimensionless
PTY	Productivity	dimensionless
RAL	Retiring Rate of Abroad Labor	person/year
RL	Retiring Rate of Domestic Labor	person/year
RTR	Retirement Rate	person/year
SAPOP	School-Age Population	person
SAR	Access Rate of School-Age Population	person/year
SCR	Revenue Rate of Sues Canal	$/year
SCRT	Ratio of Children Attend Schools	dimensionless

TD	Rate of Departure of Draftees Under Training	person/year
TMF	Anticipated Total Military Force	person
TP	Training Period	year
TPOP	Total Population	person
TRR	Revenue Rate of Tourist	$/year
TXRT	Ratio of Taxes	dimensionless
TXRV	Revenue Rate of Taxes	$/year
USMN	Allocation Factor	dimensionless
VDR	Ratio of Professional	dimensionless
VMF	Professionals	person
WWF	Fraction of Woman Working	dimensionless

APPENDIX B

MODEL LISTING

```
*       EGYPT-4
NOTE    ==================================================
NOTE                     DEMOGRAPHIC SECTOR
NOTE    ==================================================

L       SAPOP.K=SAPOP.J+(DT)(SAR.JK-AAR.JK)              DS1
N       SAPOP=12.2                                       DS2
R       SAR.KL=DELAY1(BR.JK,6)                           DS3
R       BR.KL=(ADPOP.K)(BRF.K)                           DS4
A       BRF.K=TABLE(TBRF,EDRT.K,0,100,20)                DS5
T       TBRF=.05/.048/.046/.038/.030/.02
R       AAR.KL=DELAY1(SAR.JK,12)                         DS6
A       EDRT.K=SMOOTH(SCRT.K,12)                         DS7
A       SCRT.K=MIN(EDEX1.K/EDC,99)                       DS8
A       EDEX1.K=EDEX.K/SAPOP.K                           DS9
A       RPRCH.K=EDRT.K*((1-PRCH)+PRCH*NOISE())           DS10
A       AERT.K=DLINF3(RPRCH.K,4)                         DS11
A       EDEX.K=GOT.K*EDP                                 DS12
C       EDP=0.2                                          DS13
C       EDC=0.65                                         DS14

L       ADPOP.K=ADPOP.J+(DT)(AAR.JK-RTR.JK)              DS15
N       ADPOP=22                                         DS16
R       RTR.KL=ADPOP.K/APL.K                             DS17
A       APL.K=(1/DRF.K-18)(1-HLF.K)                      DS18
A       HLF.K=TABLE(THLF,PSEX1.K,0,500,100)              DS19
T       THLF=.20/.12/.10/.10/.08/0.0
A       PSEX1.K=PSEX.K/TPOP.K                            DS20
A       PSEX.K=GOT.K*PSP                                 DS21
C       PSP=0.5                                          DS22

L       TPOP.K=TPOP.J+(DT)(BR.JK-DR.JK)                  DS23
N       TPOP=46                                          DS24
R       DR.KL=(TPOP.K)(DRF.K)                            DS25
A       DRF.K=TABLE(TDRF,CNS1.K,0,1000,200)              DS26
T       TDRF=.025/.019/.016/.0145/.0135/.013
A       CNS1.K=CNS.JK*INFC/TPOP.K                        DS27

NOTE    ==================================================
NOTE                      MILITARY SECTOR
NOTE    ==================================================

L       VMF.K=VMF.K+(DT)(AVF.JK-DVF.JK)                  MS1
N       VMF=TMF*VDR                                      MS2
R       DVF.KL=VMF.K/APL.K                               MS3
R       AVF.KL=(TMF*VDR)+(0.01*DAT.K)-VMF.K              MS4
L       DUS.K=DUS.J+(DT)(ADUS.JK+TD.JK-DDUS.JK)          MS5
N       DUS=0.75*TMF*(1-VDR)                             MS6
R       DDUS.KL=(DUS.K+DAT.K)/DP                         MS7
R       ADUS.KL=DRQ.K*ARF.K                              MS8
A       DRQ.K=(VMF.K/VDR)-DUS.K                          MS9
```

```
L       DAT.K=DAT.J+(DT)(ADAT.JK-TD.JK)                       MS10
N       DAT=0.25*TMF(1-VDR)                                   MS11
R       TD.KL=DAT.K/TP                                        MS12
R       ADAT.KL=DRQ.K*(1-ARF.K)                               MS13
A       ARF.K=AERT.K*NRMRN(USMN,0.1)/1000                     MS14
C       VDR=.25                                               MS15
C       TMF=0.5                                               MS16
C       TP=0.5                                                MS17
C       DP=2                                                  MS18

NOTE    ==================================================
NOTE                    LABOR SECTOR
NOTE    ==================================================

L       DLB.K=DLB.J+(DT)(AL.JK+LBT.JK-RL.JK-AAL.JK)           LS1
N       DLB=11                                                LS2
R       RL.KL=DLB.K/APL.K                                     LS3
R       AL.KL=MIN(DLB.K*INFC*INV.JK/CAP.K,IWF.K)              LS4
R       LBT.KL=DELAY3(ALBT,2)                                 LS5
A       ALBT.KL=DLB.K*(1-INFC)*INV.JK/CAP.K                   LS6
A       IWF.K=MAX(ADPOP.K*WWF-DLB.K-ALB.K-
X         DAT.K-DUS.K,0.0)                                    LS7
A       WWF.K=TABLE(TWWF,EDRT.K,0,1,0.2)                      LS8
T       TWWF=0.5/0.6/0.68/0.74/0.78/0.80
A       ALW.K=TABLE(TALW,ALB.K,0,2.5,0.5)                     LS9
T       TALW=25000/23000/15000/10000/5000/2500
R       AAL.KL=ALB.K*AALF.K                                   LS10
A       AALF.K=TABLE(TAALF,LWRTI.K,0,1,0.2)                   LS11
T       TAALF=0.0/.01/.018/.02/.021/.021
A       LWRTI.K=(ALW.K-DLW.K*5)/ALW.K                         LS12
A       DLW.K=MAX(PRD.JK/5/DLB.K,500)                         LS13
L       ALB.K=ALB.J+(DT)(AAL.JK-RAL.JK)                       LS14
N       ALB=1                                                 LS15
R       RAL.KL=ALB.K/APL.K/ABF                                LS16
C       ABF=0.8                                               LS17

NOTE    ==================================================
NOTE                    CAPITAL SECTOR
NOTE    ==================================================

L       ANI.K=ANI.J+(DT)(PRD.JK+OTI.JK+
X         LNSA.JK-INV.JK-CNS.JK-GEX.JK                        CS1
N       ANI=10                                                CS2
R       PRD.KL=PTY.K*CAP.K*EXP(0.65*
X         LOGN(DLB.K/CAP.K))                                  CS3
R       OTI.KL=TRR.K+SCR.K+OLR.K+ALR.K+TXRV.K                 CS4
A       TRR.K=TABLE(TTRR,POPDN,0,300,60)                      CS5
T       TTRR=50/5000/2500/800/80/50
A       POPDN.K=TPOP.K/HABA.K                                 CS6
L       SCR.K=SCR.J*(1+0.1*DT/TIME.K)                         CS7
L       OLR.K=PLR.J*(1+0.1*DT/TIME.K)                         CS8
N       SCR=500                                               CS9
```

```
N       OLR=500                                          CS10
A       ALR.K=ALB.K*ALW.K/2                              CS11
A       TXRV.K=TXRT.K*CAP.K*INFC                         CS12
R       LNSA.KL=MAX(MNI-ANI.K,0.0)                       CS13
R       INV.KL=ANI.K*INVF.K                              CS14
A       INVF.K=TABLE(TINVF,TXRT,0,1,.2)                  CS15
T       TINVF=0.3/.25/.20/.10/.05/0.0
L       TXRT.K=TXRT.J+(DT)(MNI.K-MLB.K)(TXRT.J)          CS16
A       MLB.K=TABLE(TMIWF,IWF.K,0,5,1)                   CS17
T       TMLB=0.0/.015/.027/.037/.045/.05
A       MNI.K=TABLE(TMNI,NI.K,0,10E4,2E4)                CS18
T       TMNI=.05/.045/.037/.017/.001/0.0
R       CNS.KL=MIN(PRD.KL,TPOP.K*MCNS1*INFC)             CS19
R       GEX.KL=MEX.K+PSEX.K+EDEX.K+
X         HSEX.K+NCEX.K                                  CS20
L       CAP.K=CAP.J+(DT)(INV.JK-CDR.JK)                  CS21
N       CAP=7.5E3                                        CS22
R       CDR.KL=CAP.K/ALC                                 CS23
C       ALC=20                                           CS24

NOTE    ==================================================
NOTE                     HOUSING SECTOR
NOTE    ==================================================

L       GHSB.K=GHSB.J+(DT)(GCNST.JK-GDMOL.JK)            HS1
N       GHSB=0.8                                         HS2
L       PHSB.K=PHSB.J+(DT)(PCNST.JK-PDMOL.JK)            HS3
N       PHSB=7.2                                         HS4
R       GDMOL.KL=GHSB.K/HSAL                             HS5
R       PDMOL.KL=PHSB.K/HSAL                             HS6
R       GCNST.KL=MIN(HSEX.K/HSC,HSDM.K)                  HS7
C       HSC=5E-3                                         HS8
A       HSEX.K=GOT.K*HSP                                 HS9
C       HSP=0.15                                         HS10
A       HSDM.K=MAX(FMNM.K-GHSR.K-PHSB.K,0.0)             HS11
A       GHSR.K=GHSB.K*INFC                               HS12
A       FMNM.K=TPOP.K/AVFM                               HS13
C       AVFM=5                                           HS14
R       PCNST.KL=HSDM.K*CNSTF.K                          HS15
A       CNSTF.K=TABLE(TCNSTF,FLOC.K,0.0,1.0,0.2)         HS16
T       TCNSTF=0.5/0.4/0.2/0.1/0.03/0.0
A       FLOC.K=(GHSB.K+PHSB.K)*HSA/HABA.K/5              HS17
C       HSA=5E-4                                         HS18
L       HABA.K=HABA.J+(DT)(NCM.JK)                       HS19
N       HABA=2.8E5                                       HS20
R       NCM.KL=NCMEX.K/NCMC                              HS21
A       NCMEX.K=GOT.K*NCMP                               HS22
C       NCMP=0.15                                        HS23
C       NCMC=3E-3                                        HS24
C       HSAL=60                                          HS25
```

```
NOTE    ==================================================
NOTE                   OUTPUT STATEMENT
NOTE    ==================================================

OPT     PR                                              OT1
PLOT    TPOP=P,ADPOP=A,SAPOP=S                          OT2
PLOT    EDRT=E,AERT=X                                   OT3
PLOT    VMF=V,DUS=D,DAT=T                               OT4
PLOT    DLB=D,ALB=A,IWF=I                               OT5
PLOT    ANI=I,CAP=C,GOT=G                               OT6
PLOT    PRD=D,OTI=O,CNS=N,INV=V,GEX=G                   OT7
PLOT    GHSB=G,PHSB=P,HSDM=M                            OT8

PRINT   TPOP,ADPOP,SAPOP,EDRT,AERT                      OT9
PRINT   VMF,DUS,DAT                                     OT10
PRINT   DLB,ALB,IWF                                     OT11
PRINT   ANI,CAP,GOT,PRD,OTI                             OT12
PRINT   CNS,INV,GEX                                     OT13
PRINT   GHSB,PHSB,HSDM                                  OT14

SPEC    DT=.5/PLTPER=2/PRTPER=2/LENGTH=60               OT15

NOTE    ==================================================
NOTE                   EXPERIMENTATION
NOTE    ==================================================
C       INFC=1.0                                        EX1A
C       PRCH=0.0                                        EX1B
C       USMN=0.0                                        EX1C
RUN
C       INFC=.9                                         EX2A
C       PRCH=.3                                         EX2B
C       USMN=2                                          EX2C
RUN
```

Bibliography

1. Clark, Lieutenant Colonel Thomas D. Jr., USAF. Professor of Systems Management, AFIT/EN, Wright-Patterson AFB OH. Course SM 7.71, "Simulation for Policy Analysis," Lectures. Summer Quarter 1983.

2. Clark, Lieutenant Colonel Thomas D. Jr., USAF; M. M. Kabil; and M. I. Mostafa. "An Analysis and Simulation of an Experimental Suez Canal Traffic Control System". Proceedings of the Winter Simulation Conference, Washington D.C., December 11-14, 1983.

3. Coyle, R. G. Management System Dynamics. New York: John Wiely & Sons, 1978.

4. Forrester, Jay W. Collected Papers of Jay W. Forrester. Cambridge MA: Wright-Allen Press, Inc.; 1975.

5. --------. Industrial Dynamics. Cambridge, MA: The MIT Press, 1980.

6. --------. Principles of Systems. Cambridge, MA: The MIT Press, 1980.

7. --------. The System Dynamics National Model: Understanding Socio-Economic Behavior and Policy Alternatives, Technological Forecasting and Social Change, 1976.

8. --------. Urban Dynamics. Cambridge, MA: The MIT Press, 1979.

9. --------. World Dynamics. Cambridge, MA: The MIT Press, 1971.

10. Forrester, Jay W. and Peter M. Senge. "Tests for Building Confidence in System Dynamics Models," in A.A. Legasto, Jr. and others, eds., System Dynamics. Amsterdam: North-Holland Publishing Company, 1980.

11. "General Publication about Egypt," Press & Information Bureau, Embassy of the Arab Republic of Egypt, Washington DC, 1983.

12. Graham, Alan K. "Parameter Estimation in System Dynamics Modeling," in A.A. Legasto and others, eds.,

System Dynamics. Amsterdam: North-Holland Publishing Company, 1980.

13. Greenberger, Martin and others. Models in the Policy Process: Public Decision Making in the Computer Era. New York NY: Russell Sage Foundation, 1976.

14. Greenwood, William T. Decision Theory and Information Systems: an Introduction to Management Decision Making. Cincinnati OH: South-Western Publishing Company, 1969.

15. Hall, Roger I. "A System Pathology of an [illegible]ganization: the Rise and Fall of the Old Saturday [illegible]ening Post," Administrative Science Quarterly, 21: [illegible]-211 (June 1976).

16. Hare, Van Court, Jr. Systems Analysis [illegible] Diagnostic Approach. New York NY: Harcourt, Brace & World, Inc., 1967.

17. Helmi, Yehia K. Impact of Computer Technology on Government Policy in Egypt. Ph. D. Dissertation. Cairo University, Cairo, Egypt, 1979.

18. Hsu, William L. and Anthony C. Picardy. "A Model of Saudi Arabia National Development," Development Analysis Associates, Inc., Cambridge MA, 1980.

19. Juran, J. M. Quality Control Handbook (Third Edition). New York NY: McGraw-Hill Book Company, 1962.

20. Keen, Peter G. W. and Michael S. Scott Morton. Decision Support Systems: an Organizational Perspective. Reading MA: Addison-Wesley Publishing Company, 1978.

21. Mader, Chris. Information Systems: Technology, Economics, Applications, Management. Chicago IL: Science Research Associates, Inc.; 1979.

22. Meadows, Dennis L. and Others. Dynamics of Growth in a Finite World. Cambridge, MA: Wright-Allen Press, Inc., 1974.

23. Meltzer, Morton F. "Information: the Ultimate Management Resource; How to Fined, Use, and Manage it." AMACOM, a Division of American Management Associations, New York NY, 1981.

24. Nicholson, W. Microeconomic Theory: Basic Principles and Extensions. Hinsdale IL: The Dryden Press, 1978.

25. Nyrop, Richard F. and others. Area Handbook for Egypt

(Third Addition). Washington DC: Government Printing Office, 1976.

26. O'Brien, Games J. Management Information Systems: Concepts, Techniques, and Applications. New York NY: Van Nostrand Reinhold Company, 1970.

27. Peterson, Willis L. Principles of Economics: Macro (Thrid Edition). IL: Irwin, Inc., 1977.

28. Picardi, Anthony C. and Alan McK. Shorb. "Simulating Saudi Arabia's Oil Export Strategy" Simulation, January 1983: 20-27.

29. "Prime minister's Report to the People Assembly Council," Al-Ahkbar of Egypt, 31 (9487):1-10 (November 7,1983).

30. Pugh, Alexander L. III, DYNAMO User's Manual (Fifth Edition). Cambridge, MA: The MIT Press, 1970.

31. Randers, Jorgen, ed. Elements of the System Dynamics Method. Cambridge, MA: The MIT Press, 1980.

32. Richardson, George P. and Alexander L. Pugh III. Introduction to System Dynamics Modeling with DYNAMO. Cambridge, MA: The MIT Press, 1981.

33. Roberts, Edward B. The Dynamics of Research and Development. New York NY: Harper & Row Publishers, 1964.

34. Roberts, Nancy and others. Introduction to Computer Simulation: the System Dynamics Approach. Reading MA: Eddison-Wesley Publishing Company, 1983.

35. Samuelson, Paul A. Economics: an Introductory Analysis (Six Edition). New York NY: McGraw-Hill Book Company, 1964.

36. Schoderbek, Charles G. and others. Management systems: Conceptual Considerations. Dallas TX: Business Publications, Inc.; 1980.

37. Siegel, Paul. Strategic Planning of Management Information Systems. New York NY: Petrocelli Books, 1975.

38. Statistical Yearbook: Arab Republic of Egypt, 1952-1979. The Central Agency for Public Mobilization and Statistics, Cairo, Egypt, 1980.

39. Voich, Dan, Jr. and others. Information Systems for

Operations and Management. Cincinnati OH: South-Western Publishing Company, 1975.

40. Watson, Robert D. A Systems Approach to Investigate the Optimum Cost-Effectiveness of a Generalized Management Information System. Ph.D. Dissertation. University of Oklahoma, 1970.

41. Weil, Henry B. "Industrial Dynamics and MIS," in F. Warren McFarlan and others, eds., Information Systems Administration. New York NY: Holt, Rinehart and Winston, Inc., 1980.

42. Whittemore, Bruce J. A Generalized Decision Model for the Analysis of Information. Ph.D. Dissertation. The Ohio State University, Colombus OH, 1972.

43. Whittenberg, Captain Edward L. and Captain Alan H. Woodruff, USAF. "Weapon System Acquisition Policy: A System Dynamics Model and Analysis." Unpublished master's thesis. LSSR 13-82, AFIT/LS, Wright-Patterson AFB OH, September 1982.

VITA

Colonel Magdy Kabil was born on 1 October 1946 in Elsharkia, Egypt. He received the degree of Bachelor of Science in Mechanical Engineering from Ain Shams University, Cairo in July 1967. He received a Diploma in Operations Research from Cairo University, Cairo in 1978; a Diploma in Military Operations Research from the Military Technical College in 1980; and a Master of Science in Industrial Engineering from the Ain Shams University in 1980. He is a member of the Operational Research Society of Egypt. He has served in the Operational Research Department for two years until entering the School of Engineering, Air Force Institute of Technology, in June 1982.

Permanent address: 10 Esmael Kamal Street
Heliopolis, Cairo
Egypt.

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

AD-A141051

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION: UNCLASSIFIED

1b. RESTRICTIVE MARKINGS:

2a. SECURITY CLASSIFICATION AUTHORITY:

2b. DECLASSIFICATION/DOWNGRADING SCHEDULE:

3. DISTRIBUTION/AVAILABILITY OF REPORT: APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

4. PERFORMING ORGANIZATION REPORT NUMBER(S): AFIT/GOR/OS/83D-6

5. MONITORING ORGANIZATION REPORT NUMBER(S):

6a. NAME OF PERFORMING ORGANIZATION: School of Engineering

6b. OFFICE SYMBOL *(If applicable)***:** AFIT/ENG

7a. NAME OF MONITORING ORGANIZATION:

6c. ADDRESS *(City, State and ZIP Code)***:** Air Force Institute of Technology, Wright-Patterson AFB, Ohio 45433

7b. ADDRESS *(City, State and ZIP Code)***:**

8a. NAME OF FUNDING/SPONSORING ORGANIZATION:

8b. OFFICE SYMBOL *(If applicable)***:**

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER:

8c. ADDRESS *(City, State and ZIP Code)***:**

10. SOURCE OF FUNDING NOS.

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT NO.

11. TITLE *(Include Security Classification)***:** See Box 19

12. PERSONAL AUTHOR(S): Mohamed Magdy Kabil, B.S., M.Sc., Colonel, Egypt.

13a. TYPE OF REPORT: MS Thesis

13b. TIME COVERED: FROM ______ TO ______

14. DATE OF REPORT *(Yr., Mo., Day)***:** 1983 December

15. PAGE COUNT: 112

16. SUPPLEMENTARY NOTATION:

Approved for public release: IAW AFR 190-17.
Lynn Wolaver 7 May 84
LYNN E. WOLAVER
Dean for Research and Professional Development
Air Force Institute of Technology (ATC)
Wright-Patterson AFB OH 45433

17. COSATI CODES

FIELD	GROUP	SUB. GR.
5	1	

18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)***:**
Simulation
System Dynamics
Information
Egypt

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

Title: A System Dynamics Approach to Measuring the Value of Information
Thesis Chairman: Thomas D. Clark, Jr., Lieutenant Colonel, USAF

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS ☐

21. ABSTRACT SECURITY CLASSIFICATION: Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL: Thomas D. Clark, Jr., Professor

22b. TELEPHONE NUMBER *(Include Area Code)***:**

22c. OFFICE SYMBOL: AFIT/OS

DD FORM 1473, 83 APR — EDITION OF 1 JAN 73 IS OBSOLETE.

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

Developing a computerized national information system in Egypt is under investigation. The justification for introduction of such a system is discussed through a System Dynamics approach. The value of information is assessed by studing the effects of changes in information quality attributes on the national development process.

The study provides a System Dynamics model of the national development process. Building upon the governmental policy for development, the model is divided into five main sectors; demographic, military, labor, capital, and housing sector. The five sectors are integrated and tested as a single unit.

In the model construction, decisions are modeled as a combination of information flows describing the status and objectives of the system. Information entering a decision is assumed to be available with certain levels of accuracy and timeliness. Those levels are changed through two experiments which measure different effects on the objectives of national development. Finally, recommendations are introduced for further research which will enhance the model's usefulness for both information evaluation and other policies of development.

FILME